

ST. CLAIR TUNNEL
(St. Clair River Tunnel)
Under the St. Clair River, between Port Huron,
Michigan, and Sarnia, Canada
Port Huron
St. Clair County
Michigan

HAER No. MI-67

HAER
MICH
74-POHU,
3-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD

National Park Service
Northeast Region
U.S. Custom House
200 Chestnut Street
Philadelphia, PA 19106

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Location: Under the St. Clair River, between Port Huron, Michigan, and Sarnia, Canada

UTM: A: 17.382520.4757260 C: 17.385690.4756920
B: 17.382470.4757150 D: 17.385650.4756820

Quad: Port Huron, MI, 1:24,000

Dates of Construction: 1888-1891; 1907-1908; 1958

Engineer: Joseph Hobson and others

Present Owner: St. Clair Tunnel Company, 1333 Brewery Park Boulevard, Detroit, Michigan 48207-9998

Present Use: Railroad tunnel

Significance: The St. Clair Tunnel was the first full-sized subaqueous tunnel built in North America. Joseph Hobson, the Chief Engineer, successfully combined three significant new technologies--a tunnel shield driven by hydraulic rams; a cast iron tunnel lining; and the use of a compressed air environment. This tunnel eliminated a major bottleneck in the rail transportation system linking the American midwest with its eastern markets.

Project Information: This documentation is the result of a Memorandum of Agreement among the Michigan State Historic Preservation Office, the Advisory Council on Historic Preservation, the Department of the Army, Corps of Engineers, Detroit District and the Canadian National North America Railroad as a mitigative measure before the closing of the tunnel. It was completed in June 1993 by Charles K. Hyde, Wayne State University, Detroit, Michigan 48202

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SUMMARY

The Grand Trunk Railway of Canada operated a large railway system by 1880, when it completed lines linking Chicago to the United States east coast. The Port Huron to Sarnia crossing of the St. Clair River, which depended on railroad car ferries, became a serious bottleneck for the Grand Trunk in the early 1880s. Sir Henry Whatley Tyler, president of the Grand Trunk Railway, decided that a tunnel was the solution. In October 1884, the Grand Trunk chartered the St. Clair Frontier Tunnel Company as a Canadian corporation to construct the tunnel and Tyler put the Canadian engineer Joseph Hobson in charge of the project.

The Grand Trunk also chartered the Port Huron Railroad Tunnel Company in Michigan in October 1886, and in November 1886, the railroad merged the twin companies to form the St. Clair Tunnel Company, which built the tunnel and operated it until 1958. Hobson made two failed attempts to drive the tunnel by traditional means, in December 1886 - July 1887 and in April - July 1888. After completing a detailed set of borings along the tunnel route in May - July 1888, Hobson decided to design a tunneling shield and to start tunneling from a point nearly one-third of a mile from the riverbank. He excavated great open cuts on both sides of the St. Clair River starting in January 1889 and began shield tunneling on the U.S. side in July 1889 and on the Canadian side in September 1889. Hobson introduced compressed air between March and May 1890. The two shields met on 30 August 1890 and the St. Clair Tunnel officially opened on 19 September 1891. Hobson had successfully combined three innovative techniques for the first time in the construction of a large-size subaqueous tunnel--the tunneling shield, a cast iron tunnel lining, and the use of a compressed air work environment.

This tunnel has undergone only minor changes since its opening. Following the deaths of ten men by asphyxiation between January 1892 and October 1904, the Grand Trunk electrified the tunnel, a project it completed in February 1908. The railroad lowered the tracks in 1949 to allow taller freight cars to use the tunnel. Diesel locomotives went into service in September 1958 and the railroad installed new ventilation equipment to handle the diesel fumes.

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THE NEED FOR A RAILROAD TUNNEL UNDER THE ST. CLAIR RIVER

In the late 1850s, the towns of Sarnia, Ontario and Port Huron, Michigan, straddling the St. Clair River at the outlet of Lake Huron, emerged as connecting points for trunkline railroads linking the American midwest with the east coast via Canada. In 1858, the Great Western Railway of Canada built a line from London, Ontario, on its Niagara Falls-Windsor main line, to Sarnia. The following year, the Grand Trunk Railway of Canada finished a line linking Point Edward, just north of Sarnia, with Toronto and through its existing lines, with Montreal and Portland, Maine. In November 1859, the Grand Trunk Railway also leased the just-completed Chicago, Detroit, and Canada Grand Trunk Junction Railroad Company line between Detroit and Port Huron. By connecting with the Michigan Central Railroad running between Detroit and Chicago, the Grand Trunk Railway had created a "system" that enabled it to ship goods from Chicago to the east coast. An alternative route had emerged earlier with the completion of the Great Western Railway from Windsor to Niagara Falls in 1854. Goods could travel on the Michigan Central Railroad from Chicago to Detroit, then continue via the Great Western from Windsor to Niagara Falls, where the cars could transfer to the New York Central running from Buffalo to Albany, and finally, reach New York City on the Hudson River Railroad. Both routes depended upon railroad car ferries to move the rolling stock across the St. Clair River at Port Huron/Sarnia and the Detroit River at Detroit/Windsor.¹

The Grand Trunk Railway opened a third route to the eastern seaboard in 1873, when it completed its International Suspension Bridge across the Niagara River between Fort Erie, Ontario and Buffalo, New York. The Grand Trunk soon engaged in a fierce struggle with railroad tycoon Cornelius (Commodore) Vanderbilt (1794-1877) to dominate traffic between Chicago and the east coast. In 1869, Vanderbilt had gained control of the Lake Shore and Michigan Southern Railroad, which extended from Chicago to Buffalo, and already owned the New York Central, giving him command over a line from Chicago to New York. In 1876, Vanderbilt also gained mastery of the Michigan Central and a bankrupt line called the Canada Southern, which ran from Buffalo to Windsor. After his death in 1877, his son William took over his railroad empire.

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William Vanderbilt tried to choke the Grand Trunk by charging it prohibitive rates to use the Michigan Central tracks. The Grand Trunk Railway had no choice but to create its own line to Chicago. Starting in 1879, it gained control over several lines which it consolidated as the Chicago & Grand Trunk Railway in 1880. The Grand Trunk also bought the Great Western Railway in 1882, protecting its southern Canada route to the eastern seaboard. By the mid-1880s the Grand Trunk system within Michigan included its main line extending from Port Huron to Chicago via Flint, Durand, Lansing, and Battle Creek; a second major line extending from Detroit to Pontiac, Durand, Grand Rapids, and Grand Haven on Lake Michigan; a line from Port Huron to Pontiac and Jackson; one from Port Huron to Detroit; and spurs to Saginaw and to Michigan's Thumb. The traffic destined for the east coast went to Port Huron for transport across the St. Clair River.²

In the early 1860s, the Grand Trunk unloaded freight from cars on one side of the St. Clair River, moved the goods across the water on a side-wheel steamer W.J. Spicer and then reloaded the freight onto railroad cars on the other side. They briefly used a "swing ferry," a barge holding railroad cars that was attached to a 1,000 foot-long chain, and was propelled across the river by the current. In 1872, the steam-powered propeller ferry International, which had three tracks and could hold a total of 21 cars, replaced the swing ferry. It could transport up to 400 cars per day across the river. In 1875, the Grand Trunk added a second ferry, the Huron, with a capacity of 24 cars. As the volume of traffic crossing the St. Clair River rose dramatically in the 1880s, the logistics problems became staggering. In 1888, the Grand Trunk moved roughly 297,000 freight cars, 28,000 passenger cars, and 8,000 baggage and mail cars across the St. Clair River. Assuming an average of 330 full working days in the year (counting Sundays as one-third of a day), the Grand Trunk transferred an average of roughly 1,000 cars per day. To carry this volume, both car ferries operated around the clock and had to complete one crossing per hour. According to one estimate, by the mid-1880s, the Grand Trunk carried one-third of all the freight between the midwest and New England.³

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The ferry operation across the St. Clair River was costly, time-consuming, and sometimes disruptive to the Grand Trunk's normal traffic patterns. The ferries ran between Fort Gratiot on the Michigan side and Point Edward on the Ontario side of the river, both located just south of the outlet of Lake Huron. Both ferry docks were three miles from the main lines, so using the ferries added an extra six miles to the route and even when the crossing went smoothly, meant a delay of at least half an hour. The winter and early spring brought the additional problem of ice on the St. Clair River, often accompanied by fog. The Grand Trunk operated a powerful icebreaking tug, the M.F. Merrick, to accompany the ferries, but sometimes the ice was too thick even for the ice breaker and traffic would stop for several days. The current moved at 6-8 miles per hour, increasing the threat of ice jams.

Disruptions to traffic were particularly a problem in the spring, when huge ice floes from Lake Huron would jam the river, freeze over at night, and create vast ice packs. Delays of a few days might not spell disaster for most Grand Trunk customers, but was unacceptable for those shipping dressed beef from Chicago to the east coast. Gustavus Swift had begun the practice of shipping dressed meats kept fresh in insulated cars with ice that the railroad had to replenish along the way. The Grand Trunk became a leader in providing special services to Swift and other packers and carried 138,000 tons of dressed meats in 1885 alone. For the Grand Trunk, dressed meat became its third most important freight by the mid-1880s, exceeded only by wheat and livestock.⁴

The Grand Trunk did not have many options in removing this bottleneck. The volume of shipping on the St. Clair River, said to exceed that of the Port of New York, precluded any moveable bridge, such as a bascule (draw) bridge or swing bridge. Any structure extending into the river would need the approval of the U.S. Army Corps of Engineers. The powerful Lake Carriers' Association, representing the shipping interests, would vehemently oppose a bridge. The opposition of both organizations had quickly killed plans for a bridge across the Detroit River offered by the Michigan Central Railroad in the 1870s. Given the flat topography, a high bridge, such as a suspension bridge, would require extremely long and prohibitively expensive approaches.⁵

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PLANNING AND BUILDING THE ST. CLAIR TUNNEL

Sir Henry Whatley Tyler (1827-1908), president of the Grand Trunk Railway from 1874 to 1895, was an early and persistent proponent of a tunnel under the St. Clair River. It is worth noting that he was the chairman of a commission that endorsed the construction of a tunnel connecting England and France across the Straits of Dover in 1874. As early as November 1879, Tyler instructed Sir Joseph Hickson, the Grand Trunk's general manager from 1874 to 1890, to investigate alternate ways to cross the St. Clair River. In February 1883, Hickson hired Montreal engineer Walter Shanley to do a feasibility study for a tunnel under the river. Walter Shanley, with the help of his brother Francis, had taken over the stalled Hoosac Tunnel project in northwestern Massachusetts in late 1868, and in 1874, completed this five-mile long railroad tunnel. Shanley did not conduct any engineering studies of the St. Clair River area, but he nevertheless suggested that the Grand Trunk build a tunnel south of Port Huron and Sarnia, about three miles south of the ferry crossing.⁶

Tyler, Hickson, and Walter Shanley considered several means of crossing the St. Clair River before deciding to bore a tunnel under the river bed. A bridge, with long, gradual approaches, would cost at least \$5 million and would face vehement opposition from the U.S. shipping interests. Hickson asked Shanley to consider a "trench and tube" tunnel, where they would sink an iron tube in a trench excavated in the river bottom. That design was proposed for a tunnel under the Thames in London by Messrs. Maynard and Cooke. Shanley argued that a trench and tube design would also bring strong opposition from navigation interests, who would complain that construction would likely interfere with shipping. He believed that they could drive a brick-lined, double-tracked tunnel through the clay under the river bed three miles south of Lake Huron for about \$2 million, using standard tunneling methods. In mid-November 1884, seven months after being named Chief Engineer of the tunnel project, Joseph Hobson sent Hickson a 22-page letter endorsing the route and tunnel design suggested by Shanley. Hobson believed that the tunnel was technically feasible and that improved knowledge of tunneling would enable the Grand Trunk to solve any problems it might encounter.

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Planning the tunnel began in earnest when the Grand Trunk Railway incorporated the St. Clair Frontier Tunnel Company in Canada on 19 April 1884. Sir Henry Tyler placed Joseph Hobson (1834-1917) in charge of the tunnel design and construction. Born in Guelph, Ontario, Hobson had previously served as the engineer for the International Bridge over the Niagara River, completed in 1873. Hobson then worked as the assistant chief engineer for the Great Western Railway and in 1875, became chief engineer. After the Grand Trunk acquired the Great Western in 1882, Hobson became the chief engineer of the Great Western Division of the Grand Trunk.⁸

On 18 October 1886, the Grand Trunk established a U.S. subsidiary, the Port Huron Railroad Tunnel Company, which merged with its Canadian counterpart on 9 November 1886 to form the St. Clair Tunnel Company. The principal officers of the new company were: president, Sir Joseph Hickson; vice president, Lewis James Seargeant; and secretary-treasurer, Robert White. Seargeant replaced Hickson as president before the tunnel was completed. Thomas E. Hillman became first assistant engineer and M.S. Blaiklock second assistant engineer. Other important appointments included Thomas H. Murphy as superintendent of excavation and J.T. Eames as mechanical superintendent.⁹

Given a previous failed effort to build a railroad tunnel under the Detroit River between Detroit and Windsor, Ontario, Hobson understandably proceeded with caution in planning the tunnel under the St. Clair River. Both river bottoms consisted of similar soft blue clay. James F. Joy, the president of the Michigan Central Railroad, had promoted a Detroit River tunnel and starting construction in 1872. The tunnel was to extend a total of 8,000 feet, with 3,000 feet under the Detroit River, and was to have an inside diameter of 18.5 feet, with two-foot thick brick walls. A smaller drainage tunnel was to be first driven under the main tunnel. Excavation work in 1872-1873 extended the drainage tunnel 1,220 feet under the river on the American side and roughly 450 feet on the Canadian side. But when the workers faced sudden inundations of sand and water into the excavations, the Michigan Central Railroad stopped all work and allowed the tunnels to flood.¹⁰

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In 1885, Hobson and Thomas E. Hillman, his first assistant engineer, made borings of the river bottom some 50 feet south of the intended tunnel line, to avoid disturbing the ground through which they planned to drive the tunnel. Using a pile driver mounted on a scow, they drove 6-inch diameter wrought iron pipes through the material of the river bottom down to the bedrock below to collect samples of the strata the tunnel would pass through. Because they made only eleven borings over the entire width of the river, some 2,500 feet, they had at best a rough sample of the river bottom. The findings were hardly encouraging. The river had a maximum depth of 40.5 feet. Between the water and the underlying bedrock (porous shale) were three layers or strata of material--a river bed of sand, gravel, and small boulders ranging from 2 feet in depth to about 15 feet; a mixture of quicksand and blue clay about 10 feet thick; and a layer of blue clay about 21 feet thick. This layer of blue clay was soft, but tenacious like putty and permeated with water, making it an inherently unstable material through which to drive a tunnel.¹¹

Hobson recommended to Sir Henry Tyler that they drive a small horizontal drift through the center of the eventual location of a full-size tunnel to test the material and to experiment with different methods of working the clay. Hobson planned, at least through 1887, to bore a tunnel 25 feet in outside diameter, which he would line with brick laid in Portland cement. The brick walls would be 2.50 feet thick, yielding a tunnel with an inside diameter of 20 feet. The St. Clair Tunnel Company hired the firm of William SooySmith and Company (SooySmith & Son) to sink shafts on both riverbanks down to the level of the proposed tunnel and then drive an experimental drift 8 feet in diameter along the center of the tunnel route. The tunnel company accepted SooySmith's bid of \$59,200 on 17 November 1886. General William SooySmith was an experienced engineer who had done deep foundation work for bridges. He planned to sink the shafts, each 6 feet by 14 feet and lined with 12-inch square timbers, to the level of the full-sized tunnel. Shaft-sinking began on 8 December 1886 on the Port Huron side and two days later on the Sarnia side. The Sarnia shaft reached a depth of 82 feet on 29 January 1887 and the Port Huron shaft extended 92 feet vertically by 19 February.¹²

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Sooysmith then drove drifts that were 8 feet in outside diameter and lined with 12-inch square timbers cut in wedge-shaped pieces to form an arch, producing a tunnel with an inside diameter of 6 feet. The drift from the Port Huron shaft extended only 33 feet when the diggers encountered very soft clay and Sooysmith decided on 4 April 1887 to shift all of his effort to the Sarnia side. He began the drift from the Sarnia shaft on 7 March and by 15 April, this extended 278 feet to the west.¹³

The tunnelers encountered a pocket of natural gas on 15 April and then serious flooding the following day. Before they abandoned the Sarnia drift, the workmen installed a wooden bulkhead at the end of the tunnel to prevent the flow of additional natural gas and water into the workings. The drift and shaft filled with water and Sooysmith stopped all work until he began pumping water out of the workings on 9 May. Two days later, the flame from a lantern touched off an explosion, producing minor injuries. Work resumed in late June after extensive pumping removed all of the water. The Sooysmith abandoned the work on 19 July 1887 and allowed the drifts to fill with water. He lost \$5,482 on the work he completed and forfeited a \$15,000 performance bond. In late September 1887, the St. Clair Tunnel Company decided to complete the tunnel on its own and to resume work quickly on the project.¹⁴

Hobson also conducted a more detailed set of borings along the line of the tunnel to establish the contours of the river bottom and the strata above the clay more precisely. Using a scow, they drove six-inch diameter pipes down only to the top of the clay, at intervals of 20 feet along the center line of the tunnel route. They began the work on 7 May and completed it on 16 July 1888, with a total of 110 borings taken. Heavy boat traffic on the river hampered the effort. Passing ships struck the scow and dislodged it from its moorings several times during the 70-day work period. These borings showed that the clay stratum was at most only about 38 feet thick at the middle of the river. A planned tunnel excavation 21 feet in diameter did not leave much room to maneuver. Since Hobson viewed the shale underlying the clay and the river above as equally dangerous, he decided to drive the tunnel roughly midway between the two hazards.¹⁵

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Hobson and the St. Clair Tunnel Company officials considered several new options for the tunnel project between September 1887 and February 1888. On 24 September 1887, Hobson concluded that soil conditions required that they use either "the pneumatic process, the freezing process, or the use of an iron shield with hydraulic machinery to move it forward." He did not think that the pneumatic process was practical and because he had no knowledge of the freezing process, Hobson argued for the use of a shield. He estimated the cost of a single-track tunnel with approaches at \$2,370,000. By 24 December 1887, Hobson had decided to use a cast iron lining instead of the standard brick masonry lining. Using cast iron would reduce the diameter of the bore by 4 feet (from 25 feet to 21 feet), speed the work, and make waterproofing the lining much easier. In late February 1888, Hobson awarded a contract to build two shields to the Hamilton Bridge and Tool Company. He revised his cost estimate on 3 July 1889 to \$2,650,000, reflecting the additional costs of a cast iron lining. Hobson was right on target, with the tunnel eventually costing \$2.7 million in total.¹⁶

Hobson made one final effort to excavate the tunnel from shafts sunk close to the river bank. He intended to construct a shield at the bottom of the shaft and remove the excavated material by hoisting it up the shaft. In April 1888, Hobson began to sink a new pair of shafts, one on each side of the river. They were roughly 75 feet from the water's edge, had inside diameters of 23 feet, and were supported by brick linings 2.50 feet thick. The Port Huron shaft went to a depth of 58 feet and ultimately served as a ventilation shaft. The Canadian shaft extended to a depth of 98 feet, but filled with water and clay as quickly as they could remove the material. Hobson abandoned this strategy by the summer of 1888 and adopted a more radical approach--to excavate the tunnel using a shield and to begin the work from two large open cuts well back from the river. The open cut on the Port Huron side extended 52 feet below grade, was about 200 feet wide, and began roughly 1,800 feet from the river. The Sarnia open cut was 60 feet deep, 260 feet wide, and began about 2,000 feet from the river bank. Hobson began work on the open cuts in January 1889 and tunneling began on the American side on 11 July 1889. A landslide at the Sarnia cut delayed the start of tunneling there until 24 September.¹⁷

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Hobson was the first engineer to combine three innovative methods in constructing a tunnel with a large cross-section-- a tunneling shield driven by hydraulic rams, a cast iron tunnel lining, and the use of compressed air to protect the workings from an influx of quicksand and water. Hobson did not invent any of these techniques, but combined them effectively for the first time in an extremely difficult and ambitious project. Marc Isambard Brunel (1769-1849) invented the tunneling shield, which he patented in 1818 and used in driving a tunnel under the Thames in London, a project that he began in 1825 and completed in 1843. The first Thames tunnel had arched brick masonry walls. Peter William Barlow (1809-1885) patented a round tunnel shield in 1864 and 1868. His understudy, James Henry Greathead (1844-1896) in turn used a version of Barlow's shield in building a second Thames tunnel, the Tower Subway, completed in 1869. Greathead's use of a cast iron lining in the Tower Subway was a major breakthrough that allowed him to complete the project in less than a year. Screw jacks advanced Brunel's shield and the Barlow/Greathead shield.

When Alfred Ely Beach (1826-1896), the editor of Scientific American, drove a 312-foot long experimental tunnel under Broadway in New York City in 1869, he used a circular shield driven by hydraulic rams. His 8-foot diameter tunnel used brick masonry walls on the straight segments and a cast iron lining on the curved sections. Beach was probably well aware of Barlow's patents, so his shield was not a particularly innovative design, although his use of hydraulic rams to advance the shield was novel. Nineteenth-century writers invariably called cylindrical tunnelling shields used in the United States "Beach shields," regardless of their design. James Henry Greathead later combined all these advances and used compressed air in engineering the London and Southwark subway tunnel, built in 1886-1890. Greathead's system, with only minor modifications made by Hobson for the St. Clair Tunnel, has remained to this day the basic technique for driving tunnels in soft ground. The only notable change in technology over the past century is the use of mechanical digging machinery instead of hand labor for the removal of material.¹⁸

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Once Hobson had decided to use a tunnel shield, he designed one which resembled those built by Beach and Greathead. A column in Engineering News on 8 November 1890 claimed that the only information Hobson had on the Beach and Greathead shields came from Henry S. Drinker's book, Tunneling, Explosive Compounds, and Rock Drills (New York, 1878). But a letter to the same journal, published on 22 November 1890, claimed that Greathead had given Sir Henry Tyler, the president of the Grand Trunk Railway, shield drawings to pass on to Hobson. Scientific American simply called Hobson's shields "Beach hydraulic shields." Engineering News believed that Hobson's shields most closely resembled Beach's, but conceded that Hobson's design had unique features as well. More recent scholarship has emphasized its similarity to the Greathead shield. Hobson's shield was twice the size of Greathead's and nearly three times the diameter of Beach's.¹⁹

Both the engineering profession and the public recognized the importance of the St. Clair Tunnel project. Engineering News had three stories on the tunnel between January 1889 and May 1890 before running a detailed five-part series between early October and late December 1890. Scientific American had three feature articles on the project between August 1890 and December 1891 and Harper's Weekly ran stories in February and October 1891. Engineering News offered this assessment in October 1890:

The most renowned achievements in all departments of human activity owe their importance and fame to the magnitude of the obstacles surmounted. There is now approaching completion near the outlet of Lake Huron, a railway tunnel beneath a river, which, by reason of the difficulties successfully overcome, and the importance of the completed work, is entitled to high rank among the great engineering works of the continent. Because of its importance and the fact that the method of working is in many respects an entire novelty, we have secured, through the courtesy of the Chief Engineer, Mr. Joseph Hobson, complete details of the work and the methods and the machinery employed.²⁰

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The Hamilton Bridge and Tool Company of Hamilton, Ontario built both tunnel shields. Hobson had hoped to avoid paying import duties by having an American firm build the shield used on the Port Huron side of the river, but he was unable to find one able to complete the work. Because of their size and weight (80 tons), the Hamilton firm shipped the shields to Sarnia and Port Huron in pieces and then assembled them. J.D. Eames devised a way to roll the assembled shields to the bottom of the open cuts so they ended in the proper position to start tunneling. He eased each shield down wooden skidways using steel cables anchored around piles driven at the top of the descent in a maneuver that took 80 minutes.

The cylindrical tunnel shields, each fabricated from 1-inch steel plates, had an outside diameter of 21 feet 6 inches and were 15 feet 3 inches long. The steel shell at the front of the shield was planed to create a cutting edge. Two horizontal and three vertical partitions in the front segment of the shield served as reinforcement for the steel shell. The horizontal partitions also served as platforms for the excavators. The shield had a bulkhead of one-half inch steel plate only four feet from the rear edge of the structure. The bulkhead had only two openings, through which the workers passed all the blue clay. Each opening had a door which the men could close to seal the front of the shield to prevent water or quicksand from entering the tunnel.²¹

A set of 24 hydraulic rams or jacks placed around the circumference of the shield pushed it forward nearly two feet at a time. The firm of Watson & Stillman of New York, which had built the equipment for Beach's 1868 shield, manufactured the hydraulic rams. Each ram had two cylinders, one of 8 inches diameter, used to force the shield forward, and one of 2 3/8 inches, used to draw back the large plunger or piston. Although the rams had a potential stroke of 26 inches, in practice they advanced the shield only 23 inches at a time, enough to allow the erection of another lining ring. Water pressure came from by a single Worthington pump near each of the two portals. These were duplex direct-acting duplex steam engines, with steam cylinders 12 inches in diameter and water cylinders 1 inch in diameter. They could potentially produce a water pressure of 5,000 pounds per square inch, 125 tons per ram, or a total of 3,000 tons for the entire shield.

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The greatest pressure ever required to move the shield through the soft blue clay was 1,700 pounds per square inch, or a total of 960 tons. J. T. Eames, the mechanical superintendent for the project, devised a system of valves to allow two men to control all 24 rams. Normally, they would use all the rams at once, but they could also operate each ram individually to make corrections in the shield alignment.²²

When the clay appeared stiff, the diggers often worked two or three feet ahead of the tunnel shield. They constantly sampled the ground about ten feet ahead with augers, checking for gas, water, and quicksand. In the early stages of excavating, one digger, John Ordowski of Port Huron, invented a tool that replaced the ordinary shovels used to dig the clay. The knife-like device, with handles for two men, would "cut" a slice of clay roughly a yard long and several inches thick at a time. Only two or three men of the crew of 22 diggers in the shield removed the clay from the shield proper. Another 4 men loaded the clay into cars that shifts of horses pulled along a light rail line to the tunnel portal. There, a pair of derricks picked up the car bodies and moved them from the bottom of the open cut to the top of the embankment and dumped the load onto a flat car to be hauled away to a dumping site. A pair of 50 horsepower steam-driven Lidgerwood winding engines provided the power for the hoists.²³

The tunnel lining and the means used to assemble it were notable features of this project. The completed lining consisted of 3,852 connected rings, each 21 feet in outside diameter and 18 1/4 inches wide. Each ring consisted of 13 curved segments, each 2 inches thick, 18 1/4 inches wide, having a circumferential length of 4 feet, 15/16 inches, and a key piece measuring 9 7/8 inches in circumferential length. Each of the 13 main segments weighed between 1,000 and 1,050 pounds, giving each ring a total weight of nearly 7 tons. A total of 50,076 main lining segments were cast, along with 3,852 key pieces. The cast iron lining weighed 28,000 tons, or 9,333 pounds per lineal foot of tunnel. The Grand Trunk Railway foundry at Hamilton supplied one-third of the castings and the Detroit Wheel & Foundry Company of Detroit, Michigan, the remainder.

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Each of the fourteen segments comprising a single tunnel ring had flanges on all four interior edges, to allow the workers to bolt it to the adjoining radial segment to make up a single ring and then to the adjoining ring along the circumference of the two rings. The flanges for the circumferential joints were $2 \frac{3}{8}$ inches thick, while the flanges for the radial joints are $2 \frac{3}{4}$ inches thick at the base and $1 \frac{5}{8}$ inches thick at the point. Each circumferential flange had 12 bolt holes 1 inch wide, while each radial flange contained 4 bolt-holes of the same size. The workers needed a total of 56 bolts, each $\frac{7}{8}$ inch in diameter, to bolt the sections of a single ring together, and 157 bolts to connect each ring with the preceding ring. Before the men brought the ring segments into the tunnel for assembly, they heated the segments in a wood fire and dipped them in a bath of melted pitch to provide additional protection against oxidation.

According to Engineering News, "The greatest novelty in the design of the segments is the means adopted for making the joints tight against leakage. For the radial joints, the abutting surfaces of the segments were planed, and between them was placed a packing piece of seasoned white oak $\frac{3}{16}$ inches thick. These were sawed to the exact size desired, and the bolt holes were bored $\frac{1}{4}$ inch larger than the bolt to allow for slight inaccuracies. After bolting in place, this wood packing piece rapidly absorbed water from the surrounding clay and in swelling closed the joint perfectly." A machine shop on site planed roughly 100 lining segments per day. The workmen packed the circumferential joints with roofing (course canvass covered with asphalt) made by the Standard Paint Company of New York. The bore created by the shield had a diameter 6 inches larger than the outside diameter of the tunnel lining. As they completed the iron lining, the tunnel workers forced cement grout into the 3-inch space between the lining and the surrounding clay to prevent the tunnel from moving.²⁴

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Hoisting the half-ton lining segments and placing them in the proper position to form the lining ring was no simple task. T.C. Tepper, the Chief Engineering of the Hamilton Bridge & Tool Company, designed a special hoist or crane to handle the segments. This circular crane revolved on a spindle attached to the center of the shield and had a counterweight attached to one end. The end of the crane arm had a vice which held the tunnel segment. The segment hoist had three separate hand-cranked gears which enabled the operator to move the segment in three dimensions. The ring was assembled starting with the center section at the bottom, proceeding upward to the key section placed directly overhead. A gang of 15 men assembled the lining, with two or three men attaching enough bolts to hold the segments in place, while the rest of the men followed closely behind and inserted the remaining bolts, using ordinary wrenches. They could completely assemble a ring in about 45 minutes.²⁵

Once the tunneling began, with shields advancing from both sides of the river, keeping the excavation and thus the tunnel properly aligned over its length of 6,026 feet was a major concern. The engineers kept the tunnel at the proper grade through the careful use of ordinary leveling instruments. Hobson built an instrument station at each tunnel portal, with a brick pier 3 feet square and 12 feet deep erected as a base for a pair of large theodolites, to guarantee no loss of accuracy due to shifting ground. A theodolite was a precision instrument much like a transit, fitted with a telescopic sight for establishing horizontal angles. Each had a 2 1/2 inch object glass and was custom-built for this project. The Stackpole Company of New York built the one used on the American side and Troughton & Simms of London built the one used on the Canadian side. The tunnel company bought one house on the Port Huron side and had it torn down to insure a clear line of sight. Hobson's assistants adjusted each theodolite to bisect the object glass of the one on the other side of the river. They placed an ordinary 7-inch Stackpole transit at each tunnel mouth and sighted on the object glass of the theodolite for a backsight and then reversed to carry the line into the tunnel. The engineers used a special tube cut through the center of the (compressed air) bulkhead to carry the line into the part of the tunnel worked under compressed air.

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The position of the shield was carefully checked every day and was never more than two inches out of the correct horizontal or vertical alignment. They made corrections by disengaging one or more of the hydraulic rams when the shield was advanced. When the two shields met on 30 August 1890 after excavating 6,000 feet of ground, they were perfectly aligned horizontally and off by only 1/4 inch vertically. The First Assistant Engineer, Thomas E. Hillman, and the Second Assistant Engineer, M. S. Blaiklock, had the responsibility of maintaining the proper line and level for the tunnel.

During tunneling, both shields gradually rotated from their initial position, while remaining otherwise correctly aligned. The American shield moved counter-clockwise roughly 20 degrees to the north between July 1889 and February 1890, but then revolved in a clock-wise direction so that when the shields met on 30 August 1890, it was 30 degrees south of its original position. The Canadian shield revolved counter-clockwise (to the south) from the start, and ended almost perfectly aligned with the American shield, but also 30 degrees from its starting position. This rotation did not cause any serious problems for the excavation work, but would have had it been more extreme. The contemporary engineering literature offered no explanation for this phenomenon. It most likely was the result of variations in the density of the material the shield cut through.

Over the full length of the tunnel, the alignment of the lining segments changed slightly as well. On both sides of the river, the men assembling the lining placed the key piece exactly at the crown of the tunnel, but by the time the shields met in the middle of the river, both key pieces were several feet off center. If the cored bolt holes were only slightly misaligned because of small variations in the castings, a cumulative error would probably have resulted because all the bolts were screwed tight in the same direction.²⁶

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In early September 1889, after just two months of tunneling on the Port Huron side of the river, Hobson discovered to his dismay that the shield needed strengthening. He had not put the Sarnia shield into service at that point. Hobson, who was not at Port Huron at the time, sent on to Hickson a report from J.T. Eames that the front of the shield seemed unable to stand up to the pressure of the clay. Part of the leading edge bent inward nearly an inch during an advance. Eames wanted to get an expert outside consultant to examine the shield and Hobson concurred in Eames' judgement.

Hobson used the potential shield problem to raise other serious questions with Hicks. Hobson thought that they should consider using compressed air to relieve some pressure on the shield, although he had always opposed its use. Hobson argued that the St. Clair Tunnel Company should hire as a consultant Colonel W. H. Paine of New York, currently the Chief Engineer for the Hudson River Tunnel, where he was using compressed air. Paine had earlier asked Hobson for a position on the St. Clair tunnel project. Hobson also stated quite clearly in his letter of 10 September 1889 to Hicks that he wanted to resign as Chief Engineer of the St. Clair Tunnel. Hobson argued that he lacked the needed expertise and, because he had remained as Chief Engineer for the Western Division of the Grand Trunk, was unable to devote his full attention to the project.

Two days later, Hobson reported that Eames had exaggerated the apparent weakness of the front of the shield and that they were strengthening both shields at minimal cost and disruption to the work. Because the clay on the Port Huron side was becoming softer and they were also encountering small pockets of gas, Hobson urged the use of compressed air at 30 pounds/square inch, or double normal atmospheric pressure. Using compressed air would also reduce the strain on the front of the shield. Hobson concluded in a letter to Hicks on 18 September that the shield was fundamentally sound. The deflection in the shield, which had caused so much anxiety, had taken place on 26 August when the shield ran into a pocket of very hard clay. The foreman had tried to force the entire shield forward at once instead of using the rams selectively to move through the clay.²⁷

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Hobson met W. H. Paine in New York in late September and Paine agreed to visit the tunnel and make recommendations concerning the use of compressed air once the shield reached the river. Hobson asked Paine if he would accept the position of Resident Engineer for the St. Clair Tunnel. Presumably Hobson would remain the Chief Engineer, but with no on-site responsibilities. Paine declined the offer. Hickson was sufficiently concerned about Hobson's desire to resign as Chief Engineer that he wrote a long letter to Sir Henry W. Tyler, the President of the Grand Trunk Railway, on this matter. Two recent accidents on the Great Western division had greatly upset Hobson, who believed that he had too many responsibilities to adequately serve as the Chief Engineer of the Great Western Division of the Grand Trunk. Given a choice, Hobson would quit the tunnel project. To mollify Hobson, Hickson agreed to have Colonel Paine consult with Hobson on the use of compressed air, but more important, Hickson would hire a Resident Engineer to relieve Hobson of most of the day-to-day duties at the tunnel. The crisis passed, Hobson remained on the job, and Hickson never hired another engineer.²⁸

Once Hobson set the Canadian shield in motion on 21 September 1889, the work of excavating the tunnel became routinized. Six months would pass before Hobson first employed compressed air in the workings. On 28 August 1889, the Dominion of Canada government, through the Ministry of Railways and Canals, expressed confidence in the project by voting a subsidy of \$375,000, approximately 15 percent of the projected total cost of the tunnel. Almost exactly a year later, the tunnel company arranged the means of financing the project. On 26 August 1890, the St. Clair Tunnel Company issued \$2.5 million in fifty-year first-mortgage bonds paying 5 percent interest, which the Grand Trunk Railway purchased through the sale of a new stock issue.²⁹

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The tunnel project required an extensive surface plant and equipment besides the Worthington pumps that served the hydraulic rams used to advance the shields. Separate systems to provide ventilation, lighting, drainage, and compressed air were all needed for the building of the tunnel. Hobson also built a permanent drainage system for the tunnel while the tunnel excavation was in progress. The compressed air system will be treated later in this report.

A total of four Roots blowers, two at each end, provided ventilation up to the air locks at the edge of the river. Each blower had a capacity of 10,000 cubic feet per minute and sent air through a galvanized pipe two feet in diameter mounted on the roof of the tunnel. Inside the air locks, the compressed air lines, which ended near the shield, provided the ventilation. The tunnel company consciously kept the working areas well-ventilated to prevent explosions if pockets of natural gas collected in the tunnel. They placed incandescent lamps along the length of the tunnel and provided extensive lighting in the areas near the air locks and the shield. The machine shop, compressor building, and the boiler house also had electric lighting. On the Port Huron side, a pair of 200 candlepower capacity Edison dynamos provided power, while a similar pair of Ball dynamos did the same on the Sarnia side. Armington & Sims steam engines powered the dynamos.³⁰

Drainage of water from within the tunnel has never been a major concern because the tunnel itself remained largely watertight. During construction, Hobson placed two duplex portable Worthington pumps, each with a capacity of 500 gallons per minute, outside each air lock. Water that accumulated inside the air lock was forced out by pneumatic pressure through a 2-inch drainage pipe. The Worthington pumps discharged water through a 3-inch pipe that extended up small shafts near the edge of the river at Sarnia and Port Huron. After construction work ended, the tunnel company installed two steam-powered pumps, with a capacity of 500 gallons each, at the low point of the tunnel, under the river bank on the Sarnia side. The steam lines and discharge pipe from the pumps extended to the surface through the trial shaft sunk in April 1888 and later repaired. Compressed air-driven pumps replaced the original pumps by 1904.³¹

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Hobson had to design and build a more substantial drainage system to handle the large volumes of water that would collect in the bottom of the open cuts after rainstorms. The open cuts creating the approaches to the tunnel created a drainage area of 14 acres on the Canadian side and 11.5 acres on the U.S. side. On both sides of the river, stone drains at the base of the retaining walls directed water along the walls to a single sump or well hole, from which pumps removed the water. A culvert under the track connected the two drains. On the Canadian side, the water then passed through a six-foot diameter iron pipe over a distance of 160 feet to the pumping shaft, a cast iron-lined shaft 15 feet 2 inches in diameter and 81 feet deep. The contractor, Samuel Stokes of nearby Petrolia, built the pumping shaft between June and September 1889. Two large Worthington compound pumping engines were built in a pump house at the top of the shaft, with their piston rods extending down to pumps at the bottom of the shaft. The pumps discharged the water into a pipe 18 inches in diameter located near the top of the shaft and connected to the St. Clair River. On the American side, the tunnel company placed four smaller Worthington pumps in a building located on the south side of the open cut just west of the tunnel portal. They pumped water up to a drain located above the top of the cut. The pumping stations will be treated in separate reports on the pump houses.³²

Hobson introduced the use of compressed air once the shield began to pass under the river, a distance of 1,716 feet from the American portal and 1,994 feet from the Canadian portal. Compressed air was first used on the American heading on 7 April 1890 and on the Canadian heading on 20 May 1890. They built solid airtight bulkheads of brick and cement mortar 8 feet thick across the tunnel. At either tunnel heading, men, cars, and horses passed through one of two air locks, each 6 feet in diameter and 17 feet long, with iron doors. Each air lock encased one of the two sets of tracks running the length of the tunnel. They also built a small air lock, measuring 10 inches in diameter, but 25 feet long, into the bulkhead to allow long pieces of pipe to move through the barrier. On each side of the river, two 20 X 24 inch air compressors manufactured by the Ingersoll Seargent Rock Drill Company of New York supplied compressed air to the workings through a 6 inch wrought iron pipe.

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Losses of air pressure through the air locks and the bulkhead were minor, other than the small leakage that took place when men went from the high pressure sector into the low-pressure area. Originally, the air locks had a single 4-inch globe valve to equalize the air pressures, but this allowed too rapid decompression and caused many cases of the "bends," more commonly called "the benders" by the men, because their knees would buckle and they would bend over in pain. The men would frequently bleed through the nose, mouth, and ears. Three men died of the "bends" during the tunnel project and scores suffered from the disease. In time, they substituted a 1 1/2-inch valve in the air lock, slowing the rate of decompression. Even with the smaller valve, men would pass through the air lock in about 2 minutes. Engineering News believed that extending the decompression time to 5 minutes would eliminate most the cases of the "bends," but conceded that this might slow the pace of work. The number of workers in the compressed air zone at any given time was between 50 and 75.

Engineering News argued that Hobson should have used compressed air from the start of tunneling, given the soft, unstable nature of the clay. Before Hobson used compressed air, the volume of clay removed from the excavation was 50 percent larger than the volume the tunnel occupied because clay oozed into the workings from the sides and top. Once Hobson used compressed air, this discrepancy practically disappeared. The initial use of compressed air raised the pressure to 10 pounds per square inch over atmospheric, or 25 pounds per square inch total. The highest pressure employed was 43 pounds per square inch, 28 pounds above normal atmospheric pressure. The directors of the St. Clair Tunnel Company reported that the American shield ran into quicksand on 5 May 1890 and water began flowing into the tunnel. A rapid increase in the air pressure quickly stopped the leak. Horses were unable to survive in the compressed air environment, so they employed mules to haul the tram cars loaded with clay from the workings to the tunnel portals. Even after the shields met on 30 August 1890, they continued to employ compressed air until 2 October, when they began to remove the bulkheads and air locks.³³

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The tunnel project employed a large labor force from January 1889 through the formal tunnel opening in September 1891. Engineering News reported 600 men at work in February 1890 and Harper's Weekly reported a year later that an average of 700 men worked on the project. Although the two shields met in the middle of the river on 30 August 1890, much work remained unfinished. Work on the approaches, begun in August 1890, took nearly a year and employed 200 men much of the time.

Several sources give conflicting information about wages. An Engineering News article of 8 February 1890 claimed that diggers earned 17.5 cents per hour, iron men 15 cents, and all other labor 12.5 cents, all for an eight-hour day. The same journal claimed in November 1890 that all men working in the compressed air received an increase of \$1.00 per day (or 12.5 cents per hour) once work began in that environment. That seems like an extraordinary pay raise and is probably incorrect. On 11 April 1890, the Canadian diggers petitioned for an increase to 25 cents per hour, citing the difficult nature of the work, the inherent dangers of the work, and the "closeness of the air" as justification. The workers on the American side made a similar demand around the same time. Gilbert and Pratt claim that both the Canadian and the American diggers were earning 17.5 cents an hour at the time. The Canadian workers presented their demands as a petition, which they signed round-robin style along the outer edges, to prevent the St. Clair Tunnel Company from identifying the ringleaders. The tunnel management simply ignored the demands. Once the use of compressed air stopped in early October 1890, the Tunnel Company reduced wages to 12.5 cents per hour, but allowed the men to work 14 hours a day to make up the lost earnings.³⁴

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The two shields advanced toward each other at a pace that generally improved over time, after an initial learning process on both sides of the river. The monthly progress shown in the table below shows that the American shield excavated nearly 700 more feet of ground than its Canadian counterpart. This discrepancy reflects the two-month delay in starting the Canadian shield, the poor performance in the Canadian heading in May of 1890, and the more difficult ground encountered in the Canadian excavation.

MONTHLY ADVANCE OF THE TUNNEL SHIELDS
JULY 1889 - AUGUST 1890 (IN FEET)

	<u>American</u> <u>Heading</u>	<u>Canadian</u> <u>Heading</u>
1889		
July	53	-
August	144	-
September	154	73
October	127	109
November	226	188
December	267	217
1890		
January	278	292
February	274	306
March	204	293
April	182	281
May	356	97
June	354	237
July	382	201
August	311	334
TOTAL	3,310	2,629

Source: Gilbert, St. Clair Tunnel, p. 31.

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As the two shields approached each other, Hobson stopped the American shield from advancing and on 20 August, he began a six-foot drift lined with timbers through the remaining space of roughly 125 feet. He did this to allow one final check of the tunnel alignment to allow adjustments before the shields touched. The Canadian shield continued to advance and at noon on 23 August, the shields were only 89 feet apart. The next day, when only 15 feet separated the men in the drift from the American shield, someone bored an auger hole through to the other side and passed a plug of tobacco through the opening. Workers removed the remaining clay in the drift and at noon on 25 August, Hobson passed through the opening from the Canadian heading into the American side of the diggings, followed by his chief assistants and other tunnel company officials. The leading edges of the two shields finally met on 30 August 1890, but the tunnel company needed another month to complete the tunnel lining. They left the outer shells of the shields in place in the blue clay, while they removed all the internal parts. The workers had to specially cast the last ring of the lining to fit the remaining space. On 2 October 1890, Hobson stopped using compressed air.³⁵

The St. Clair Tunnel did not formally open until 19 September 1891, more than a year after the shields met, and the first freight train did not use the tunnel until 24 October 1891. Even after they finished the lining, much work remained. The men removed the bulkheads and air locks, along with the pipes carrying high-pressure water and air. Nearly two months after Hobson stopped using compressed air, the Canadian bulkhead remained in place. During construction, about 2 feet of clay filled the tunnel floor to create a base for the tramroad leading out of the tunnel. They removed the clay and cleaned the tunnel. The lower half of the tunnel was lined with brick laid in cement mortar to the depth of the flanges. They laid additional brick to form a base for the tracks and all the brickwork received a 1-inch coating of cement mortar. Hobson added this extra lining to prevent salt brine leaking from refrigerator cars and then thrown up by the wheels from corroding the tunnel walls. The Grand Trunk had seen its bridges suffer damage from salt brine and wanted to avoid this problem. They also gave the upper half of the lining a coat of asphalt paint to protect it from corrosion. On 20 January 1891, they finished all work in the tunnel.³⁶

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Excavation of the tunnel's long approaches, along with the construction of the portals, did not begin until Hobson was confident of the success of the tunnel excavation. The St. Clair Tunnel Company awarded the contract for the excavations to the firm of Nihan, Elliot & Phin of St. Catharines, Ontario, on 18 August 1890. They were to excavate an open cut measuring 60 feet deep, 260 feet wide, and roughly 3,100 feet long on the Sarnia side and 52 feet deep, 200 feet wide, and approximately 2,500 feet long on the Port Huron side. The contractor used a pair of steam-shovels at each open cut, along with several hundred men. Occasional landslides and heavy rains hindered the work on both sides of the river. The landslides forced a widening of the open cuts and the use of heavy limestone retaining walls to prevent any recurrence. The original estimates called for the removal of about 500,000 cubic yards of material from the open cuts, but the amount finally removed was considerably larger. They did not finish the approaches until September 1891, right before the formal opening.

The contract for constructing the portals went to William Gibson of Beamsville, Ontario. He built the portals and their wing walls with courses of quarry-faced (rough-cut) limestone blocks. Gibson finished the Canadian portal in early November 1890 and the American portal by late December. It is not clear from the surviving records if Gibson also built the limestone retaining walls running the length of the approaches. In total, 20,000 cubic yards of masonry were used on the portals and retaining walls.³⁷

The St. Clair Tunnel Company bought four custom heavy-duty steam locomotives to move trains through the tunnel. The Baldwin Locomotive Works of Philadelphia, the premier American locomotive manufacturer of the late nineteenth century, built them in February 1891. Each locomotive had a 0-10-0 wheel configuration and were designed as camelback engines, so they could operate in either direction and thus, the railroad did not have to turn them around after each passage through the tunnel. The weight on their 50-inch diameter drivers was 195,000 pounds, making them the heaviest engines built up to that time. They had the power to pull a 760-ton train up the long 2 percent grade at both ends of the tunnel.³⁸

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Hobson's early estimates of the total costs of construction proved remarkably accurate. The tunnel cost \$2.7 million, broken down by the following major categories of expense:

Expended on preliminary work	\$250,000
Machinery and plant	250,000
Labor, all classes	900,000
Cast iron for lining	800,000
Other Materials	100,000
Real estate, land damages, legal expenses, etc.	110,000
Permanent expenses (track, locomotives)	50,000
Approaches	200,000
Engineering, superintendence, etc.	40,000
Total	\$2,700,000

Source: Port Huron Daily Times--International Tunnel
Opening Edition, 19 September 1891, p. 3.

As the tunnel approached to completion, sightseers began to descend on the site. The tunnel company admitted a few visitors, but only with a pass signed by Hobson himself. In late November 1890, Thomas A. Edison, who grew up in Port Huron, was one of a party of ten who toured the bore. In mid-February 1891, an unnamed female reporter for the Port Huron Daily Times went through the tunnel, the first female to do so. Six months earlier, tunnel officials had refused admittance to a female reporter from Buffalo after she began taking dimensions of the machinery.³⁹

Plans for the celebration of the tunnel opening began well before the end of the project was in clear view. In mid-November 1890, a guide leading a group through the tunnel foresaw an official opening in March 1891. In early February 1891, Charles McKenzie, a director of the St. Clair Tunnel Company, predicted an opening around 15 June 1891, but it did not take place until 19 September 1891. Local reporters erroneously announced that the Grand Trunk Railway would hold a celebration banquet in the tunnel itself, with banquet tables straddling the international border.⁴⁰

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The opening of the tunnel created some friction between the Grand Trunk Railway and the forces of civic boosterism in Port Huron, including the Port Huron Daily Times. The Grand Trunk scheduled the formal opening for 19 September, to accommodate its president, Sir Henry Tyler, who was returning to England on 21 September. This was about a month earlier than the Grand Trunk had previously suggested. The Daily Times, for instance, had to rush its special tunnel opening edition into production a month early. The Port Huron newspaper had hoped for a great public celebration, including special excursion trains, parades, and walking tours, all passing through the tunnel. Given the amount of work still unfinished within the tunnel and the continuing problem of landslides along the approaches, Hobson ruled out excursion trains or walking tours. The ceremonies and events surrounding the formal opening of the tunnel were largely private in character.⁴¹

The celebration of the formal opening of the tunnel began Friday, 18 September 1891 and continued through the following day. Friday evening, the citizens of Port Huron hosted a banquet to honor Sir Henry Tyler and the Grand Trunk Railway. Over 100 attended, including all the principal officers of the Grand Trunk Railway and the St. Clair Tunnel Company, the mayors of Port Huron and Sarnia, the Governor of Michigan, and other government officials. The formal opening took place the following day, when a trainload of Grand Trunk officials and their guests rode through the tunnel from the Sarnia side to Port Huron. The train passed under two enormous floral arches built over the tracks, one on each side of the river. This party later returned to Sarnia for a more elaborate banquet in the Grand Trunk's freight house, converted for this purpose. The Sarnia banquet included over 350 guests, including Grand Trunk Railway and St. Clair Tunnel Company officials; prominent businessmen from the Great Lakes region; provincial, state, and local government officials; and representatives from the local and national press. The first freight train passed through the tunnel on 24 October 1891 and the first passenger train on 7 December 1891. The Grand Trunk then stopped the ferry service. The tunnel immediately saved the Grand Trunk two hours on the Chicago to Toronto route and \$50,000 per year spent operating the ferries.⁴²

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OPERATING HISTORY AND ALTERATIONS

The St. Clair Tunnel Company made alterations to the tunnel equipment and design features within a few years after the opening. It built a small brick pump house on the northern edge of the Canadian approach, just east of the portal. The building appeared in a photograph dated June 1893, but the precise date of construction is not known. Early in the operating history of the tunnel, the weight of the trains travelling along the tunnel approaches began to push the soil under the tracks outward against the masonry ballast wall (inner wall) of the drainage ditches that ran parallel to the track. To stabilize the roadbed and to prevent a collapse of the drainage ditch, the tunnel company placed steel beams between the ballast wall of the drainage ditches and the much larger retaining walls for the open cuts. These reinforcements are clearly visible in a photograph taken sometime before the 1908 electrification of the tunnel. The size of trees in the image suggests that the photograph dates from ca. 1900, but there is no more precise information about the date of the reinforcing.⁴³

The most significant change to the tunnel after its opening was the conversion to electric operation in 1908. The Grand Trunk Railway decided to adopt electric locomotives after a series of fatalities in the tunnel from asphyxiation. Although the tunnel locomotives burned either coke or anthracite coal to reduce smoke emissions, the locomotives nevertheless produced carbon dioxide and carbon monoxide. Both gases can cause death. The ventilation system normally took 45 minutes to clear the tunnel of all gases after a train had passed through. Joseph Hobson testified in 1897 that he had removed the original ventilating pipes after only a few years of use because they worsened tunnel ventilation. If a train passed through the tunnel without delay, the gases did not pose a threat to life. However, as a locomotive was ascending the incline leading out of the tunnel, the couplers connecting the cars were subject to great strains and would often break, leaving part of the train behind in the tunnel. This would endanger the conductor and brakeman, who normally worked from the caboose, as well as the locomotive engineer and fireman if they returned to the tunnel to retrieve the missing cars.

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The first fatal accident occurred on 31 January 1892, only three months after the tunnel opened to regular freight traffic. Following a train break in the tunnel, conductor George Hawthorne and brakeman Joseph Whalen were overcome by fumes and Hawthorne died. The breaking of couplers in the tunnel became so commonplace that more fatal accidents were inevitable. In the four years ending 30 June 1899, for example, when nearly 16,000 trains traversed the tunnel each year, a total of 278 trains broke apart in the tunnel, roughly 70 per year.

A second and more serious accident took place on 28 November 1897, resulting in the death of three men, including the engineer, one brakemen, and the conductor. The third and the worst accident happened on 9 October 1904 and produced six deaths, including two brakemen, two conductors, the locomotive engineer, and the superintendent of the Sarnia and Port Huron terminals, Alexander S. Begg. The Royal Canadian Humane Society awarded medals to ten Grand Trunk employees who aided in the rescue "for conspicuous bravery" the following summer.⁴⁴

In the wake of the third fatal accident, the Grand Trunk moved quickly to convert the tunnel to electric traction. In December 1904, the two major suppliers of electrical equipment, General Electric and Westinghouse, submitted detailed proposals to electrify all tunnel operations, including the drainage system. The Grand Trunk specified that the electric haulage system must be able to pull a 1,000-ton train between the two tunnel terminals in 15 minutes, and maintain a train speed of at least 10 miles per hour up the 2 percent grade leading out of the tunnel. The steam locomotives in use since 1891 could only pull trains of up to 760 tons. General Electric proposed a DC system of 600 volts using a third rail, but the Grand Trunk accepted a Westinghouse proposal based on the use of a 3,300-volt AC single-phase system. The Grand Trunk hired the engineering firm of Bion J. Arnold of Chicago to serve as consulting engineers for the installation of the new system. The prime contractor for the installation was Abbott-Gamble of New York City, while the American Bridge Company did the steel work. According to the Port Huron Daily Times, the entire project cost more than \$1 million.

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Although the Grand Trunk signed the electrification contract with Westinghouse in January 1906, the first electric locomotive did not pull a freight train through the tunnel until 20 February 1908. The self-contained electrical system included a large steel-framed brick powerhouse built east of the American portal, between Military Street and the St. Clair River. This plant included four 400-horsepower Babcock & Wilcox water-tube boilers fed by automatic stokers. The coal-fired boilers powered two Westinghouse-Parsons steam turbines which in turn drove a pair of Westinghouse generators producing two-phase alternating current at 3,300 volts and a frequency of 25 cycles per second. The electrical service entered the tunnel through the same vertical shaft sunk near the river bank in April 1888. The electrical power ran the full length of the tunnel, both tunnel approaches, and included trackage in the Port Huron and Sarnia freight yards. Electrification involved a 4-mile zone with a total of 12 miles of track. This system also supplied AC power to all the tunnel pumping stations; to the Port Huron and Sarnia passenger stations, roundhouses, and shops; and to the YMCA buildings at the Sarnia and Port Huron yards.⁴⁵

Inside the tunnel, special iron brackets, each with spool-shaped insulators supported 5/8-inch-thick galvanized-steel messenger cables with clamps which in turn supported the copper trolley wires. At the portals, the steel messenger cables were anchored in eyebolts embedded in the masonry blocks right below the date, "1890," where they extended, along with the working conductor, into the tunnel proper. A triangular steel shield located at the crown of the tunnel entrance served to protect the conductor from water and ice damage. Beyond the tunnel proper, overhead catenaries supported by steel towers placed 250 feet apart supported the messenger cables, with the trolley wires suspended below.

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The remaining key component of the electric haulage system was the set of six electric locomotives jointly built by Westinghouse and the Baldwin Locomotive Works. Each was a double-ended box type locomotive which operated in either direction and in multiples. Each unit had three 250-horsepower single-phase motors. Two units could pull a 1,000-ton train through the tunnel at 30 miles per hour. While the tunnel company sometimes used one unit to haul a passenger train, normally they used two units at once and considered a them a single locomotive. These electric locomotives brought a 700-ton freight train through the tunnel on 20 February 1908, marking the start of electric service.

Westinghouse Company personnel remained at the tunnel for nine months, training the tunnel employees in the use of the new equipment. For three months, both steam locomotives and the electric models were used for haulage. The steam locomotives went out of service for good on 17 May 1908. Westinghouse continued to supervise the operation of the system until they officially transferred control to the St. Clair Tunnel Company on 12 November 1908. Over time, as trains became heavier, the tunnel company needed additional haulage capacity and bought three more electric locomotives in 1927. From that time on, they routinely ran four locomotives at a time and kept the ninth as a spare.⁴⁶

Electrification allowed for new pumping equipment. At the American portal, two centrifugal pumps, each with a capacity of 4,000 gallons per minute and driven by a 100-horsepower, 3 phase, 25-cycle, 3,300 volt electric motor, were installed in the existing pump house just south of the portal. On the Sarnia side, the equipment included a pair of centrifugal pumps, each with a capacity of 5,500 gallons per minute, driven by a pair of 200-horsepower motors like those on the Port Huron side. The new electric system also provided power to light the tunnel with a total of 480 incandescent lamps placed in two rows on either side of the tunnel, about 10 feet above the level of the track. Although the electric traction system remained in use until 1958, the Detroit Edison Company supplied the power starting in May 1917, and the tunnel company scrapped its generating equipment.⁴⁷

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When the Grand Trunk Railway of Canada went bankrupt in 1923, Canadian National Railways absorbed it. The St. Clair Tunnel Company simply continued as an independent subsidiary of the Canadian National Railways. The Grand Trunk properties in Michigan, Indiana, and Illinois became the Grand Trunk Western Railroad, a subsidiary of Canadian National. Later, on 31 March 1958, the tunnel company ended its independent status and became a subdivision of CNR.⁴⁸

Two attempts to sabotage the tunnel during the two world wars created some excitement, but no real damage. In 1917, a group of pro-German conspirators planned to blow up the tunnel with a charge of dynamite which they would roll into the tunnel on a platform mounted to roller skates. The leader of this plot was Albert Karl Kaltschmidt, president of the nearby Marine City Salt Company and the head of a group of German agents who had targeted dozens of industrial and transportation facilities in southeastern Michigan and southwestern Ontario. The legal system convicted Kaltschmidt and four others and gave them various fines and prison terms. In 1940, a boxcar containing aircraft engines was set on fire in the tunnel, apparently mistaken for a trainload of high explosives that had just passed through the tunnel. The authorities never found the perpetrators.⁴⁹

In 1949, Canadian National Railways replaced the timber ties supporting the track with reinforced concrete supports and simultaneously lowered the tracks within the tunnel some 7 inches to allow taller boxcars to use the tunnel. The last change in motive power for the tunnel came on 28 September 1958, when the last electric locomotives moved trains through the tunnel, replaced by diesels. As the electric locomotives had aged, their maintenance costs skyrocketed. Canadian National Railways bought the foundry patterns from Westinghouse and had to produce its own repair parts during the last decades of electric operations. The diesel-electric locomotives in normal service on the Grand Trunk Western and Canadian National lines replaced the electric locomotives used in the tunnel. A new ventilation system with ductwork and ventilation fans at both portals allowed the diesels to operate safely.⁵⁰

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By the late 1960s, the tunnel was no longer able to handle the taller freight cars used for traffic related to the automobile industry, especially tri-level auto carriers and special 85-foot long automobile parts cars. In March 1971, Canadian National had to reintroduce railroad car ferry service between Port Huron and Sarnia using the tug Phyllis Yorke pushing the barge St. Clair. They added a second tug and barge a few years later to provide enough capacity to handle the larger volumes of traffic. A second innovation in railroad freight equipment, Canadian National's so-called "Laser" train, could use the tunnel without requiring alterations. The Laser train consists of a set of flatcars specially designed with recessed wells to carry standard freight containers.⁵¹

The Grand Trunk Western Railroad has also faced the growing popularity of "doubled-decked" container cars, also unable to use the existing tunnel, which has an inside diameter of only 19 feet 10 inches. By the beginning of the 1990s, the Grand Trunk Western decided to build a replacement tunnel north of the historic St. Clair Tunnel. The new structure will also be a single-tracked tunnel, but will have an inside diameter of 31 feet. Canadian National Railways will build it with a highly automated tunnel-boring machine at a cost of approximately \$150 million. The Grand Trunk Western also re-incorporated the St. Clair Tunnel Company and transferred ownership of the tunnel to the new corporation.⁵²

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PHYSICAL DESCRIPTION

Starting from the Port Huron side of the St. Clair River, the tunnel structure has five distinct sections. The first is the approach to the west (American) portal, measuring 2,615 feet long and 33 feet wide between the retaining walls for most of its length, but narrowing to only 20 feet wide west of the portal. The gradient is 1 foot in 50, or 2 percent. The next segment, the west grade within the tunnel, has the same gradient and extends 2,396 feet. The third segment, the middle part of the tunnel, has a slight grade of 1 foot in 1,000 (0.1 percent) toward the east and extends 1,694 feet. The east end of this middle segment is the lowest point in the tunnel. The fourth segment, the east grade within the tunnel, has a gradient of 1 foot in 50 (2 percent) and extends 1,937 feet to the east (Canadian) portal. Finally, the approach to the Canadian portal, with the same gradient of 2 percent, is 3,171 feet long, 20 feet wide between the retaining walls near the portal and 33 feet wide for most of its length. The tunnel proper measures 6,026 feet long from portal to portal, while the tunnel and its approaches has a total length of 11,810 feet, more than two miles.

The basic design of the masonry structures built to retain the earth on both sides of the approaches and produce drainage ditches and the roadbed was the same on both sides of the river. Trapezoidal-shaped retaining walls which increase in height and thickness as they approach the portals are surmounted by a course of coping stones to divert water from the walls. The retaining walls also have limestone counterforts (piers) extending into the soil behind the walls, built to provide additional support against the thrust of the soil. The counterforts were all 4 feet wide, 8 feet high, and extended 6 feet back from the inner edge of the retaining walls. Starting at the portals, they extend for about one-quarter of the length of the approaches. Paving stones, 4 feet, 6 inches wide extend inward from the base of the retaining walls and below the grade level of the roadbed to form the base for the drainage ditch. A ballast wall, 2 feet wide and 1 foot 10 inch high formed the interior wall of the drainage ditch. Finally, cross walls measuring 4 feet wide and 2 feet high extended below grade between the inner edges of the paving stones.

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The approach to the west (American) portal is 2,615 feet long overall, but the retaining walls extend only 1,656 feet westerly from the portal. Over the first 151 feet of the south retaining wall, starting at the western end, the height of the masonry increases in 3 stages from 1 foot to 4 feet, while it increases in width (thickness) from 2 feet, 6 inches to 3 feet. A segment extending 343 feet in length is 5 feet, 6 inches high and 3 feet thick. The rest of the south retaining wall, some 1,088 feet in length, was 5 feet, 9 inches high and 5 feet thick. A steel retaining wall consisting of 10-foot long steel panels bolted together has replaced a substantial section of the last segment of the original retaining wall, a total of 585 feet. The final 66 feet leading to the portal consists of the foundations for the pump house at the south border of the approach. All of the retaining wall segments are surmounted by coping stones 1 foot, 6 inches in height, with increasing widths as the width of the retaining wall grew.

The north retaining wall of the American approach has the same shape until it reaches a point 200 feet west of the portal. There, the wall takes a 90 degree turn to the south for 13 feet and then turns 90 degrees again to continue in an easterly direction to the portal. It is at this point that the distance between the retaining walls narrows from 33 feet to 20 feet, to service the single track leading into the tunnel proper. For the final 66 feet west of the portal, the retaining wall increases in height from 5 feet 9 inches to 6 feet 2 inches, and from 5 feet to 6 feet thick. A total of 33 counterforts extend 370 feet west from the portal. There are a total of 25 cross walls in the American approach, 9 of them measuring 11 feet long and the remaining 16 measuring 24 feet long. These extend a distance of 740 feet west of the portal, well beyond the last counterfort. West of the point where the approach widens from 20 to 33 feet, the cross walls are further and further apart.

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On the Canadian side, where the approach is 3,171 feet long, the retaining walls extend 2,069 feet east of the portal. The south retaining wall has dimensions comparable to those on the American approach up to roughly 450 feet east of the portal, where the walls become significantly thicker than on the American side. A section of retaining wall 7 feet thick extends for 66 feet, followed by a section 8 feet thick (301 feet long), one 12 feet thick (73 feet long), concluding at the portal with a segment 15 feet thick and 27 feet long. The counterforts extend 480 feet east of the portal and the cross walls, a total of 58, extend 1,770 feet east of the portal.

The portals and wing walls at both tunnel entrances consist of massive ashlar masonry walls made up of coursed, quarry-faced (rough-cut) limestone blocks set in cement mortar. The center or portal section is 28 feet wide, while each wing is 60 feet wide, resulting in a total width of 148 feet. The masonry structures, which extend below grade for the entire width of the open cut, are 36 feet high in the center section, but then are shortened by roughly 30 inches in a series of steps every 9 feet 4 inches proceeding up the slope of the open cutting. The ends of both wing walls are only 7 feet 4 inches high. The facing of the center (portal) section consists of 13 courses of cut limestone blocks, each 2 feet 4 inches high, and two courses, each 2 feet 6 inches high, which form the crown of the entire structure. The width of the limestone blocks varies considerably, ranging between 32 inches and 84 inches. At the center or portal section, there is a solid masonry wall 6 feet thick, a 2-foot wide drain behind it, and an additional masonry wall 3 feet thick. Flanking the portal is a battered wall, which is 3 feet thick at its base, but tapers to only 1 foot wide at the crown of the wing wall. At this point, the above-grade masonry is 14 feet thick. The battered wall also narrows as it reaches the outer edges of the wing wall, where the masonry structure is only 9 feet thick.

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The tunnel opening or portal is circular, measures 20 feet in diameter, and consists of a series of wedge-shaped arch stones (voussoirs). The wedge-shaped keystone is 4 feet high. Two courses of limestone blocks, each 2 feet 6 inches high, form the crown above the portal and wing walls. Above the keystone is a single dress-faced limestone block 6 feet wide, which carries the date, "1890" in relief. Above the date stone is a larger dress-faced limestone block measuring 12 feet long, 3 feet high at the ends, but with a low-pitched gable at the top, forming a pediment 4 feet high. It serves as the nameplate and carries the name "ST. CLAIR" in relief.

Each portal also has a pump house, described in detail in separate parts of this report. The Port Huron Pump House (1891) is a rectangular structure, 20 feet by 36 feet, with a hipped roof, and walls made from the same quarry-faced limestone blocks as the portal and retaining walls. The Sarnia Pump House (1908) is a rectangular, gable-roofed structure with a concrete foundation and brick walls, measuring 21 feet by 32 feet.⁵³

A single contractor, William Gibson of Beamsville, built the retaining walls, portals, and other masonry work at both approaches, using similar limestone blocks. The major difference between the two sides is the greater length of the Canadian (Sarnia) approach. The total amount of limestone masonry used on the American (Port Huron) approach, exclusive of the portal, was 6,017 cubic yards, while the Canadian approach required 9,082 cubic yards, for a total of 15,099 yards. The Port Huron Daily Times estimated that the total volume of masonry used for the approaches, portals, and the Port Huron Pump House was 20,000 cubic yards, probably close to the mark.⁵⁴

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A ventilation system installed in the tunnel in 1958 to remove exhaust fumes produced by diesel locomotives starts inside the tunnel, but part of the ductwork and the electric motor-driven fans extend beyond the tunnel proper. The ventilation ducts, situated along the upper part of the tunnel lining, use the lining as one of duct walls. The ducts are 32 inches wide at the base, 9 inches wide at the top, and are 7 feet 5 inches high. They extend a distance of 51 feet 9 inches into the tunnel from the portals. As they extend outside the American portal, both ducts deflect about 20 degrees away from the line of the tracks and extend 10 feet 3 inches to the point where they connect to the fans. At that point, the ducts change their roughly rectangular shape to a circular shape 48 inches in diameter at their ends. The ducts then connect to Woods Aerofoil Fans driven by 20 Horsepower electric motors. Each fan had the capacity to move 50,000 cubic feet per minute operating in the forward mode (pulling air out of the tunnel) and 32,000 C.F.M. when reversed. At the Canadian portal, the south duct and fan have the same configuration as at the American portal. The north duct, however, makes a 90 degree turn after leaving the tunnel and extends 18 feet 4 inches to the north before turning 45 degrees to the northeast and connecting to the fan. The transitional duct is 3 feet 6 inches wide and 5 feet 9 inches high. This lengthy detour diverts the duct around the Sarnia Pump House.⁵⁵

The remainder of the tunnel consists of the 6,026 feet of the original tunnel lining completed in 1891. The lower half of the tunnel lining remained covered in cement, which has cracked and fallen away in many places, revealing the original brick lining laid in cement mortar. The individual segments of the tunnel lining are clearly visible in the upper part of the tunnel. A bronze plaque marks the Canada-United States international boundary in the middle of the tunnel. Where the tunnel shields met in August 1890, the key piece on the segment of the lining that advanced from the United States is oriented about a foot to the south of the Canadian key segment, which is at the crown of the lining. The final connecting tunnel lining ring also has irregular dimensions, varying in width from roughly 6 inches to roughly 10 inches.

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At the foot of the Sarnia grade, i.e., at the low point in the tunnel, the electric motor-driven centrifugal pumps installed in 1908 are extant. These pumps, each with a capacity of 150 gallons per minute, are mounted on brackets on the south side of the tunnel lining, above the center of the tunnel. Besides these pumps, there is no surviving evidence of the electric trolley wire system used in the tunnel between 1908 and 1958. There are no other surviving interior features of note.⁵⁶

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NOTES

¹Willis F. Dunbar, All Aboard! A History of Railroads in Michigan (Grand Rapids, MI: Eerdmans Publishing Company, 1969), pp. 73, 96-97 and Clare Gilbert, St. Clair Tunnel: Rails Beneath the River (Erin, Ontario: Boston Mills Press, 1991), p. 11.

²Dunbar, All Aboard!, pp. 139, 144-148.

³Gilbert, St. Clair Tunnel, pp. 11-14 and "The St. Clair Tunnel," Engineering News, Vol. 24, 4 October 1890, p. 292.

⁴George Roy Stevens, Canadian National Railways, Vol. 1, Sixty Years of Trial and Error, 1836-1896 (Toronto: Clarke, Irwin & Company, 1960), pp. 363-365; Wanda Pratt, Tunnel Tales: The St. Clair Tunnel, 1891-1991 (Petrolia, Ontario: Link Publishing, 1988), p. 4; and T.G. La Moille, "The St. Clair River Tunnel," Harper's Weekly, Vol. 35, 28 February 1890, p. 158.

⁵La Moille, "The St. Clair River Tunnel," p. 158 and Philip Mason, The Ambassador Bridge: A Monument to Progress (Detroit: Wayne State University Press, 1987), pp. 38-41.

⁶Ralph Greenhill, "The St. Clair Tunnel," in Dianne Newell and Ralph Greenhill, Survivals: Aspects of Industrial Archeology in Canada (Erin, Ontario: the Boston Mills Press, 1989), pp. 185-186; Gilbert, St. Clair Tunnel, p. 14; Port Huron Daily Times--International Tunnel Opening Edition (Volume 20, No. 155, Part 2), 19 September 1891, p. 9; and George Roy Stevens, History of the Canadian National Railways (New York: Macmillan, 1973), pp. 74, 148.

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⁷Information derived from summaries and verbatim extracts from miscellaneous correspondence relating to the tunnel, typescript dated 3 October 1890, included in Historic Tunnel Documents from the National Archives of Canada and the National Library of Canada, compiled by Klohn Leonoff, Ltd., 1300 Central Parkway West, Mississauga, Ontario in 1991. The key letters include Sir Henry Tyler to Joseph Hickson, 18 November 1879 and 18 December 1883; Hickson to Tyler, 31 January 1880; Hickson to Walter Shanley, ? February 1883, 28 June 1883, and 14 January 1884; Shanley to Hickson, 24 November 1883 and 25 January 1884; and Joseph Hobson to Hickson, 10 November 1884.

⁸Gilbert, St. Clair Tunnel, p. 17.

⁹Ibid and La Moille, "The St. Clair River Tunnel," p. 158.

¹⁰"The St. Clair Tunnel," Engineering News, Vol. 24, 4 October 1890, p. 292.

¹¹"St. Clair Tunnel," Engineering News, Vol. 24, 4 October 1890, pp. 292-293 and La Moille, "The St. Clair River Tunnel," p. 158.

¹²The description of tunnel construction through July 1887 is based on a long article which appeared in the Port Huron Daily Times, 9 August 1887, p. 2, and from a summary of events between 17 November 1886 and 23 July 1887, found in Klohn Leonoff, Ltd., compiler, Historic Tunnel Documents.

¹³Port Huron Daily Times, 9 August 1887, p. 2 and Klohn Leonoff, Ltd., compiler, Historic Tunnel Documents.

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¹⁴ Port Huron Daily Times, 27 April 1887, p. 2; 12 May 1887, p. 2; 9 August 1887, p. 2; and 1 October 1887, p. 4; Gilbert, St. Clair Tunnel, p. 19; Port Huron Daily Times--International Tunnel Opening Edition, 19 September 1891, p. 3; Greenhill, "The St. Clair Tunnel," pp. 186-187; La Moille, "The St. Clair River Tunnel," p. 158; "The St. Clair Tunnel," Engineering News, Vol. 24, 4 October 1890, p. 293; and "President's Address," Transactions of the Canadian Society of Civil Engineers, Vol. 4 (1890), p. 62. The details of the problems encountered between November 1886 and July 1887 are confirmed by almost-daily correspondence between Thomas E. Hillman, the chief assistant engineer and Joseph Hobson over those months, found in the Grand Trunk Western Railroad Collection held by the Bluewater-Michigan Chapter of the National Railway Historical Society, Box 149. Most of the contemporary sources refer to the contractor as SooySmith and Son or as SooySmith and Co., but a few sources call him Sooy Smith.

¹⁵ "The St. Clair Tunnel," Engineering News, Vol. 24, 4 October 1890, p. 293.

¹⁶ Klohn Leonoff, Ltd., compiler, Historic Tunnel Documents and Port Huron Daily Times--International Tunnel Opening Edition, 19 September 1891, p. 3.

¹⁷ Port Huron Daily Times, 31 December 1888, p. 5 and La Moille, "The St. Clair River Tunnel," p. 158. The confused newspaper account of 31 December 1888 has work just starting in January 1889 on a 22-foot diameter shaft roughly 2,000 feet from the river, but with the tunnel excavated by means of a tunnel shield of the same diameter.

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¹⁸ Gosta E. Sandstrom, Tunnels (New York: Holt, Rinehart and Winston, 1963), pp. 209-222, 232-241; J.H. Greathead, "The City of London and Southwark Subway," Engineering News, Volume 18, 5 November 1887, p. 324; Robert M. Vogel, Tunnel Engineering: A Museum Treatment, United States National Museum Bulletin 240 (Washington, D.C.: the Smithsonian Institution, 1964, pp. 228-231, 236; and Graham West, Innovation and the Rise of the Tunneling Industry (Cambridge: Cambridge University Press, 1988), pp. 116-124.

¹⁹ Engineering News, Vol. 24, 8 November 1890, p. 425 and 22 November 1890, p. 467; "The Great Railway Tunnel Under the St. Clair River, Between the United States and Canada," Scientific American, Vol. 63, 9 August 1890, p. 87; Greenhill, "The St. Clair Tunnel," pp. 187-188; Vogel, Tunnel Engineering, p. 237; and West, Innovation and the Rise of the Tunneling Industry, p. 123.

²⁰ "The St. Clair Tunnel," Engineering News, Vol. 24, 4 October 1890, p. 291.

²¹ "The St. Clair Tunnel," Engineering News, Vol. 24, 8 November 1890, p. 425 and "The St. Clair River Railway Tunnel," Port Huron Daily Times--International Tunnel Opening Edition, 19 September 1891, p. 3. Contemporary sources are divided over the identity of the builder of the shield. They split about evenly between the Hamilton (Ontario) Bridge and Tool Company and the Tool Manufacturing Company of Hamilton. A contemporary promotional book, Hamilton, the Birmingham of Canada (Hamilton: Time Printing Company, 1893), p. 60, has a photograph of the Hamilton Bridge and Tool Company plant, but makes no reference to the Tool Manufacturing Company of Hamilton.

²² "St. Clair Tunnel," Engineering News, Vol. 24, 20 December 1890, pp. 546-547; "The St. Clair River Railway Tunnel," Port Huron Daily Times--Tunnel Opening Edition, 19 September 1891, p. 3; and La Moille, "The St. Clair River Tunnel," p. 158.

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²³ Gilbert, St. Clair Tunnel, p. 28 and "The St. Clair Tunnel," Engineering News, Vol. 23, 8 February 1890, p. 128 and Vol. 24, 20 December 1890, p. 548; and La Moille, "The St. Clair River Tunnel," p. 158.

²⁴ "The St. Clair Tunnel," Engineering News, Vol. 24, 6 December 1890, pp. 498-499 and Port Huron Daily Times, 4 April 1890, p. 3 and 17 November 1890, p. 5.

²⁵ Ibid., p. 499 and La Moille. "The St. Clair River Tunnel," p. 158.

²⁶ "The St. Clair Tunnel," Engineering News, Vol. 24, 22 November 1890, p. 457 and "The St. Clair River Railway Tunnel," Port Huron Daily Times--International Tunnel Opening Edition, 19 September 1891, pp. 6-7.

²⁷ Klohn Leonoff, Ltd., compiler, Historic Tunnel Documents, Joseph Hobson to Joseph Hickson, 10 September, 12 September, and 18 September 1889.

²⁸ Ibid., Hobson to Hickson, 27 September 1889 and Hickson to Sir Henry W. Tyler, 3 October 1889.

²⁹ Klohn Leonoff, Inc., compiler, Historic Tunnel Documents, "Agreement between Her Majesty, Queen Victoria, represented by the Minister of Railways & Canals of Canada and the St. Clair Frontier Tunnel Company, 28 August 1889" and Gilbert, St. Clair Tunnel, p. 17.

³⁰ "The St. Clair Tunnel," Engineering News, Vol. 24, 20 December 1890, p. 548.

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³¹ "The St. Clair Tunnel Drainage System," Scientific American, Vol. 65, 12 December 1891, p. 373 and Canadian Westinghouse Company, Ltd., The Substitution of Electric For Steam Operation in the St. Clair Tunnel (December 1904), p. 16.

³² Ibid.; "The St. Clair Tunnel," Engineering News, Vol. 24, 20 December 1890, p. 548; Klohn Leonoff, Ltd., compilers, Historic Tunnel Documents, Joseph Hobson to Samuel Stokes, 27 June 1889; and Port Huron Daily Times, 28 August 1889, p. 3.

³³ "The St. Clair Tunnel," Engineering News, Vol. 24, 22 November 1890, p. 457; La Moille, "The St. Clair River Tunnel," p. 158; and Klohn Leonoff, Ltd., compilers, Historic Tunnel Documents, Report of the Directors to the Shareholders of the St. Clair Tunnel Company for the Year Ended June 30, 1890, 14 August 1890.

³⁴ Gilbert, St. Clair Tunnel, p. 32; Wanda Pratt, Tunnel Tales: The St. Clair Tunnel, 1891-1991 (Petrolia, Ontario: Link Publishing, 1988), pp. 19-20; "Progress of the St. Clair Tunnel," Engineering News, Vol. 23, 8 February 1890, p. 129; and "The St. Clair Tunnel," Engineering News, Vol. 24, 22 November 1890, p. 457.

³⁵ "The St. Clair Tunnel," Engineering News, Vol. 24, 22 November 1890, p. 457; La Moille, "The St. Clair River Tunnel," p. 158; Port Huron Daily Times, 18 August 1890, p. 3; Port Huron Daily Times, 23 August 1890, p. 4; Port Huron Daily Times, 25 August 1890, p. 3; and Port Huron Daily Times--International Tunnel Opening Edition, 19 September 1891, p. 7.

³⁶ "The St. Clair Tunnel," Engineering News, Vol. 24, 6 December 1890, p. 499; La Moille, "The St. Clair Tunnel," p. 159; and Port Huron Daily Times, 24 November 1890, p. 5.

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³⁷ La Moille, "The St. Clair River Tunnel," pp. 158-159; Port Huron Daily Times, 22 December 1890, p. 4; and Port Huron Daily Times--International Tunnel Opening Edition, 19 September 1891, p. 9.

³⁸ Gilbert, St. Clair Tunnel, p. 73.

³⁹ Port Huron Daily Times, 24 November 1890, p. 5 and 17 February 1891, p. 5.

⁴⁰ Port Huron Daily Times, 17 November 1890, p. 5 and 6 November 1891, p. 5.

⁴¹ Port Huron Daily Times, 17 August 1891, p. 5; 9 September 1891, p. 5; and 14 September 1891, p. 5.

⁴² Port Huron Daily Times, 21 September 1891, pp. 4, 5, and 8, and Gilbert, St. Clair Tunnel, pp. 39-45.

⁴³ National Archives of Canada photograph, June 1893, reproduced in Newell and Greenhill, Survivals, p. 202 and photograph from the Holland-Paisley Collection, Sarnia, image H-140-28.

⁴⁴ "St. Clair Tunnel, Comparative Statement of Traffic, Year Ended June 30, 1897," and "St. Clair Tunnel Company, Report of the Directors to the Shareholders for the Year Ended June 30, 1899," found in Box 149 of the Grand Trunk Western Railroad Collection, Bluewater Michigan Chapter of the National Railway Historical Society; Gilbert, St. Clair Tunnel, pp. 45-48; and Pratt, Tunnel Tales, pp. 40-50.

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⁴⁵ Gilbert, St. Clair Tunnel, pp. 55-57; Canadian Westinghouse Company, Ltd., The Substitution of Electric For Steam Operation in the St. Clair Tunnel (December 1904), pp. 1, 17; F. A. Sager, Electrification of the St. Clair Tunnel: An Illustrated Technical Description (Montreal: Grand Trunk Western Railway, 1908), p. 10; "Electric Equipment for the Tunnel--Contract Has Been Let to Westinghouse Company of Pittsburgh," Port Huron Daily Times, 8 January 1906, p. 1; "Electric Engines Tested--Nineteen Loaded Freight Cars Drawn Through St. Clair Tunnel," Port Huron Daily Times, 21 February 1908, p. 8; "Electrification of St. Clair Tunnel Inspected by Many Distinguished R.R. Officials," Port Huron Daily Times, 12 November 1908, pp. 1, 8; and John M. Kenn, "The Saint Clair River Railroad Tunnel," Inland Seas, Vol. 31 (Fall 1975), p. 182, note 14.

⁴⁶ Gilbert, St. Clair Tunnel, pp. 57, 64, 74 and Sager, Electrification of the St. Clair Tunnel, pp. 19-20. The system installed was similar to, but not identical to the one proposed by Canadian Westinghouse in 1904, but was manufactured by Westinghouse's American operation based in Pittsburgh, presumably to avoid paying duties.

⁴⁷ Sager, Electrification of the St. Clair Tunnel, pp. 16-17 and Kenn, "The Saint Clair River Tunnel," pp. 182-183.

⁴⁸ Gilbert, St. Clair Tunnel, pp. 65, 67.

⁴⁹ Ibid., p. 61 and Pratt, Tunnel Tales, pp. 35-38.

⁵⁰ Gilbert, St. Clair Tunnel, pp. 67, 69, 71.

⁵¹ Ibid., p. 69, 71.

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⁵² Valarie Basheda, "Port Huron Tunnel Gets Green Light," The Detroit News, 31 January 1993, pp. 6,7-C.

⁵³ "St. Clair Tunnel Co. Contract For Masonry, Plan and Sections of Masonry Retaining Walls, etc., in Approaches, Traced From the Original by Valuation Engineering Office, GTR," 24 October 1917; "St. Clair Tunnel--Portal," Front Elevation and Plan, undated engineering drawing, showing the portal as built; field measurements of portal masonry; "St. Clair Tunnel Pumphouse, Pt. Huron," Drawing No. 219, Joseph Hobson, Hamilton, Ontario, 26 November 1890; and "Grand Trunk Railway, New Pump House at Sarnia, Montreal, 6 November 1907. The drawings came from the office of the Canadian National Railway Engineering Department in Toronto.

⁵⁴ Port Huron Daily Times--International Tunnel Opening Edition, 19 September 1891, p. 9. The information on the overall dimensions and layout of the tunnel, the approaches, and the portals was taken from engineering drawings, mainly "St Clair Tunnel, Profile of Proposed Tunnel and Cross Section of St. Clair River," Joseph A. Hobson, Hamilton, Ontario, 13 July 1889 and "St Clair Tunnel Co. Contract For Masonry, Plan and Sections of Masonry Retaining Walls, etc., in Approaches, Traced From the Original by Valuation Engineering Office, GTR," 24 October 1917.

⁵⁵ Based on a set of ten detailed drawings, "Supplemental Ventilation, St. Clair Tunnel," Canadian National Railways Mechanical Department, August 1958.

⁵⁶ Sager, Electrification of the St. Clair Tunnel, p. 16.

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SOURCES OF INFORMATION

- A. Architectural Drawings: The Canadian National Railway Engineering Department, 277 Front Street West, Toronto, Ontario, M5V 2X7, has an extensive collection of drawings covering all aspects of tunnel construction and operating equipment. This is a safe repository and the drawings are likely to be preserved in a permanent archive once the historic tunnel is closed.
- B. Historic Views: Several major sources of historic views were identified. The Museum of Arts and History, 115 Sixth Street, Port Huron, Michigan 48060, has about two dozen historic views. The Holland-Paisley Collection of Historical Photographs, 151 Vidal Street North, Sarnia, Ontario, has a similar number. The Canadian National Railway's archives has additional views. Many historic views are held by private collectors and are not readily accessible to researchers.
- C. Bibliography

1. Primary and Unpublished Sources:

Grand Trunk Western Railroad Collection held by the Bluewater Michigan Chapter of the National Railway Historical Society, P.O. Box 296, Royal Oak, MI 48068. Materials relating to the St. Clair Tunnel include property maps, reports of the directors of the St. Clair Tunnel Company, statements of construction expenses, and a voluminous correspondence between Thomas E. Hillman, first assistant engineer for the tunnel project, and Joseph Hobson, the chief engineer.

Klohn Leonoff, Ltd., compilers. Historic Tunnel Documents From National Archives of Canada and National Library of Canada (Klohn Leonoff, Ltd., Mississauga, Ontario, 1991). The materials include correspondence copied from the Sir Joseph Hickson Papers, MG29 A29, National Archives of Canada.

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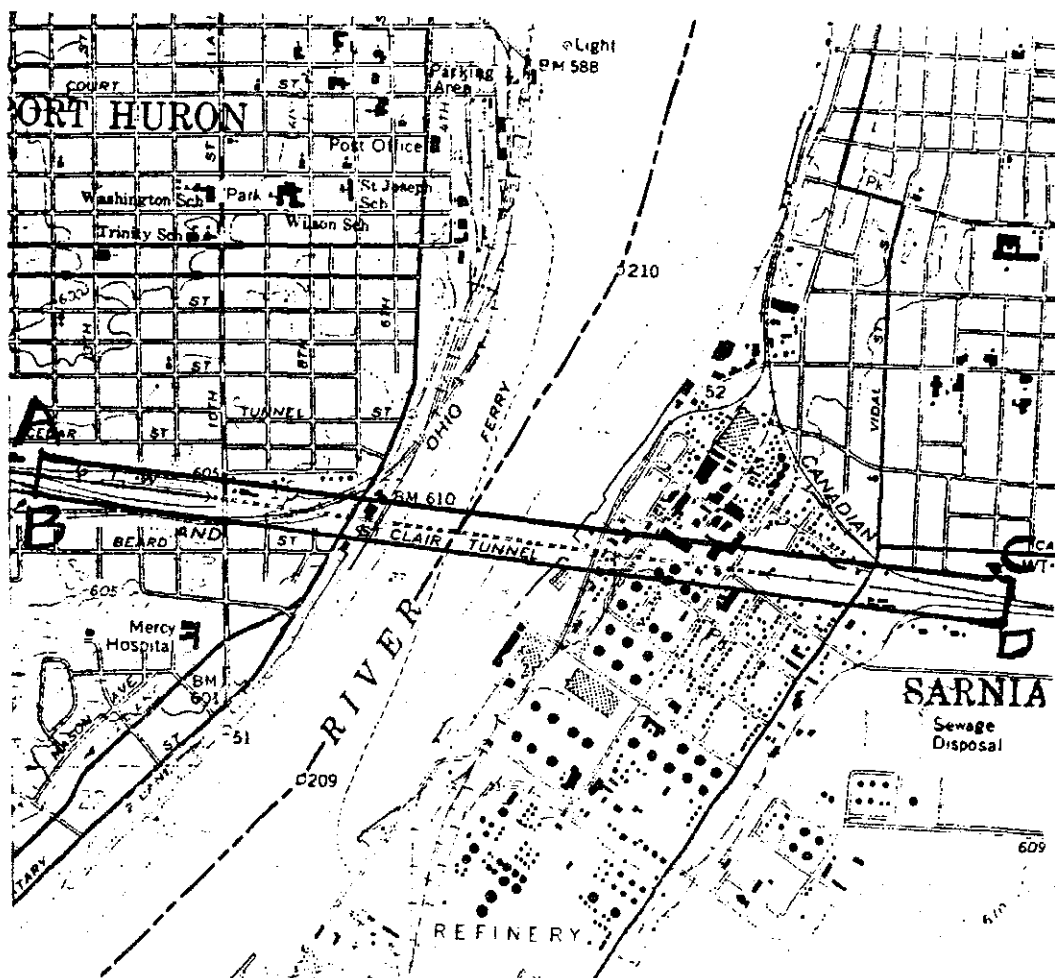
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PORT HURON, MICHIGAN QUADRANGLE

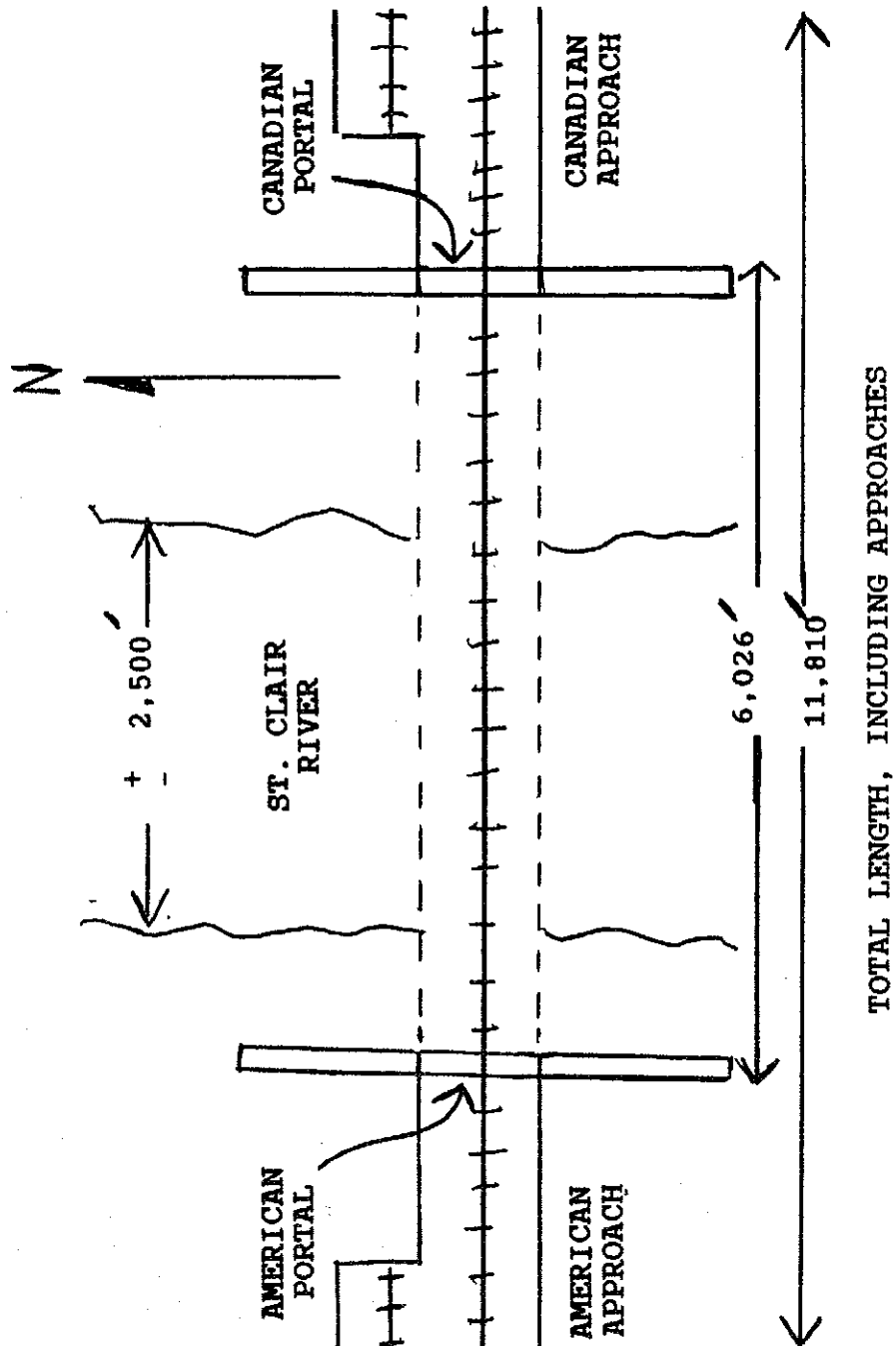
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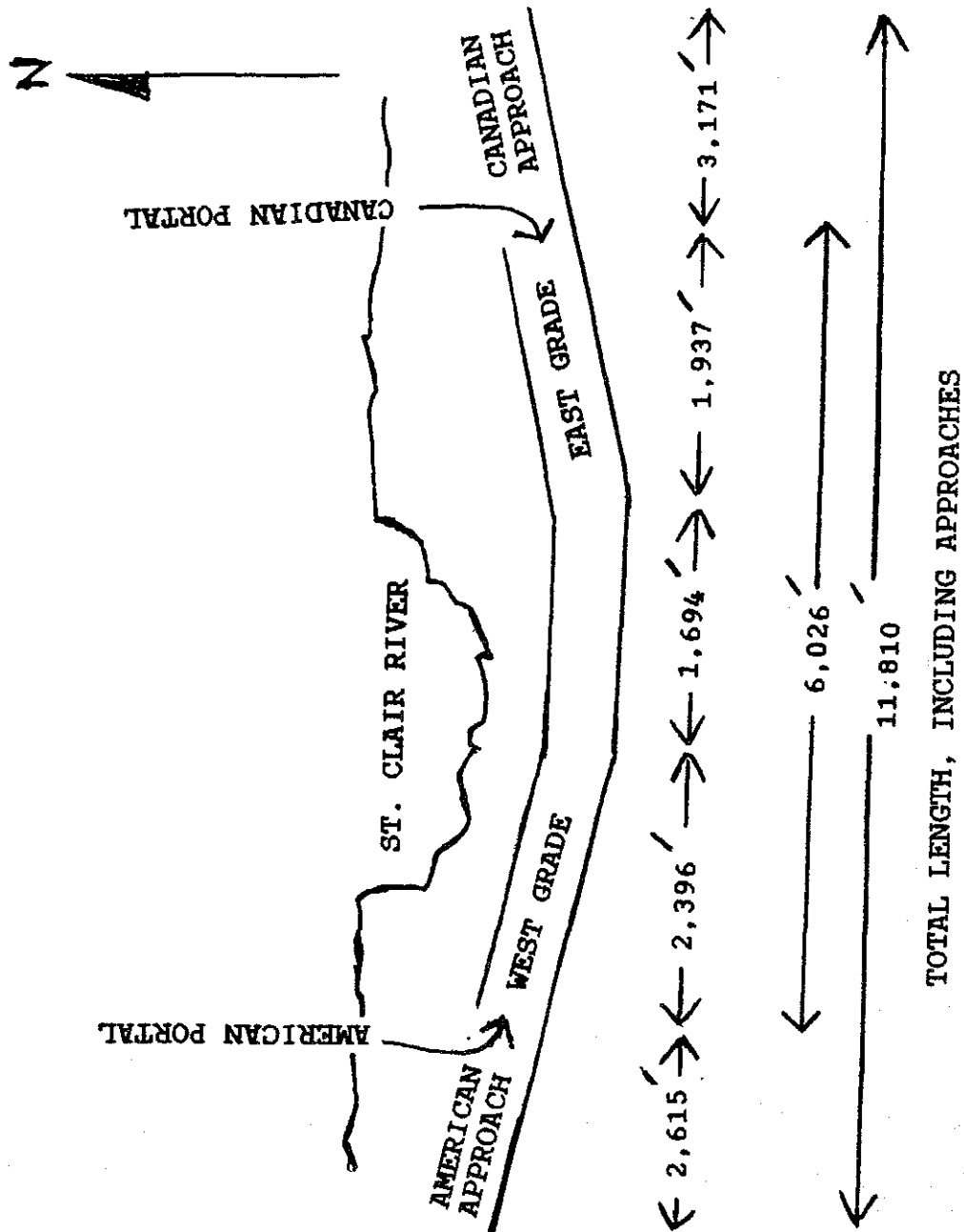
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GENERAL SITE PLAN



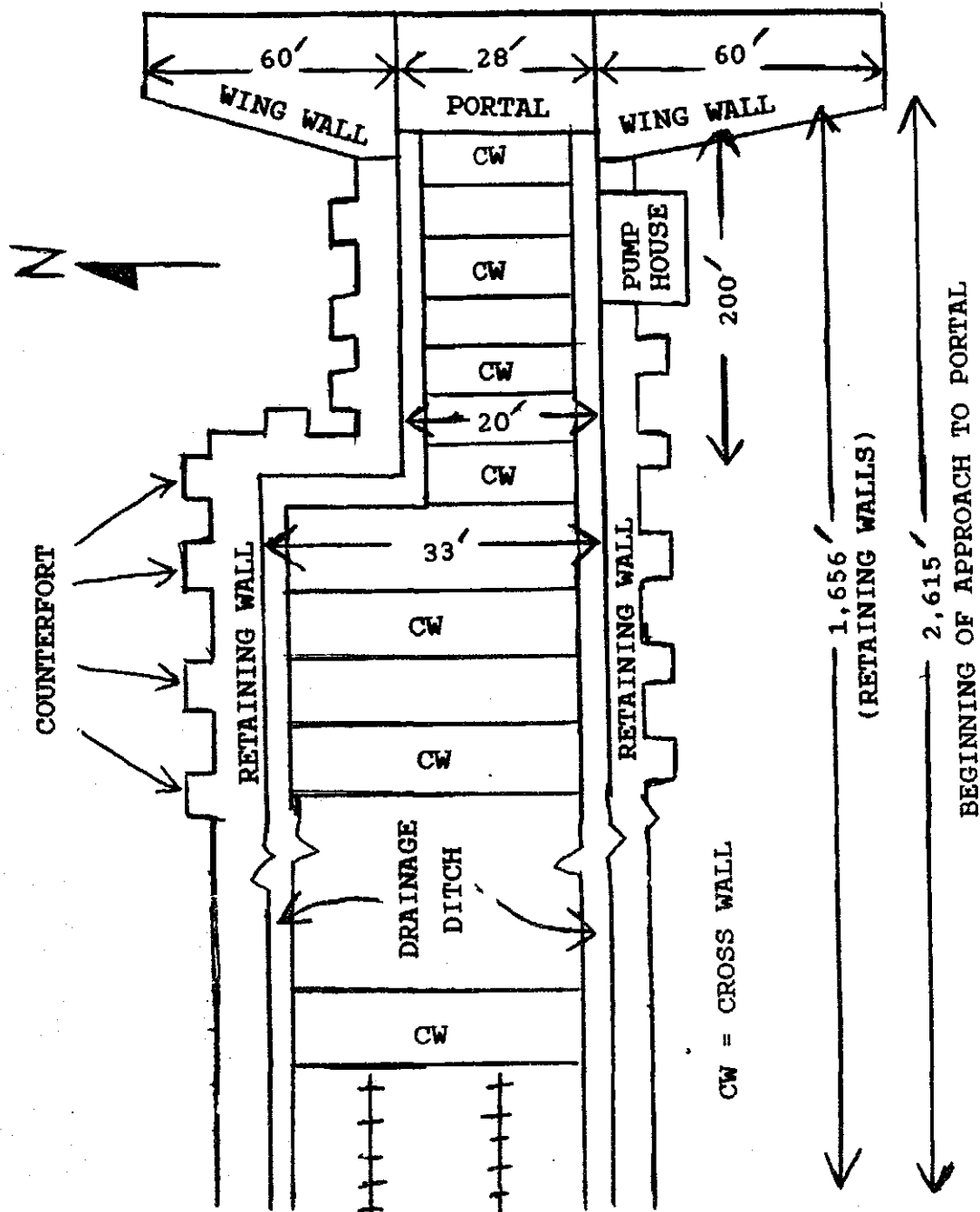
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GENERAL TUNNEL PROFILE



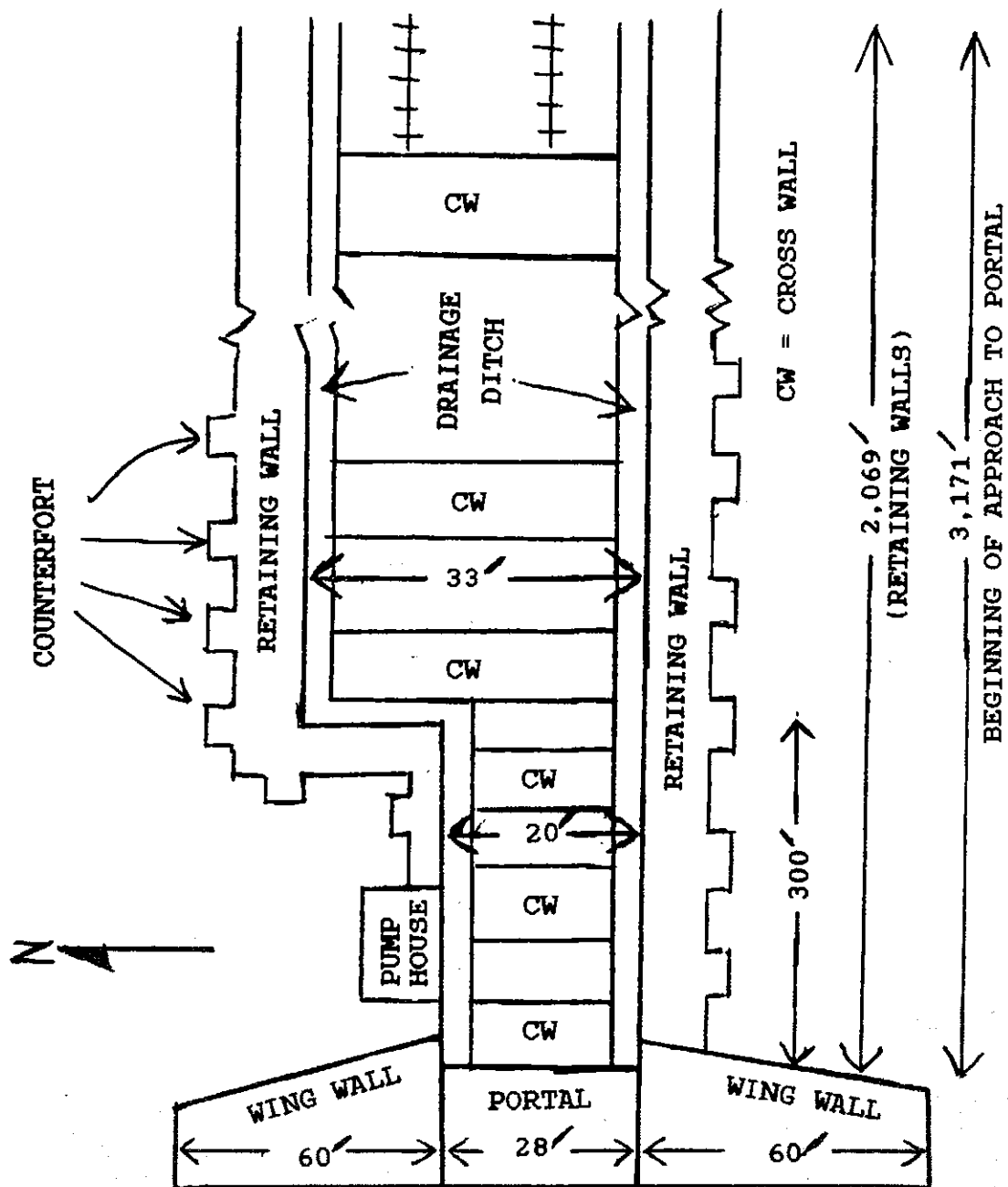
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SITE PLAN, AMERICAN APPROACH



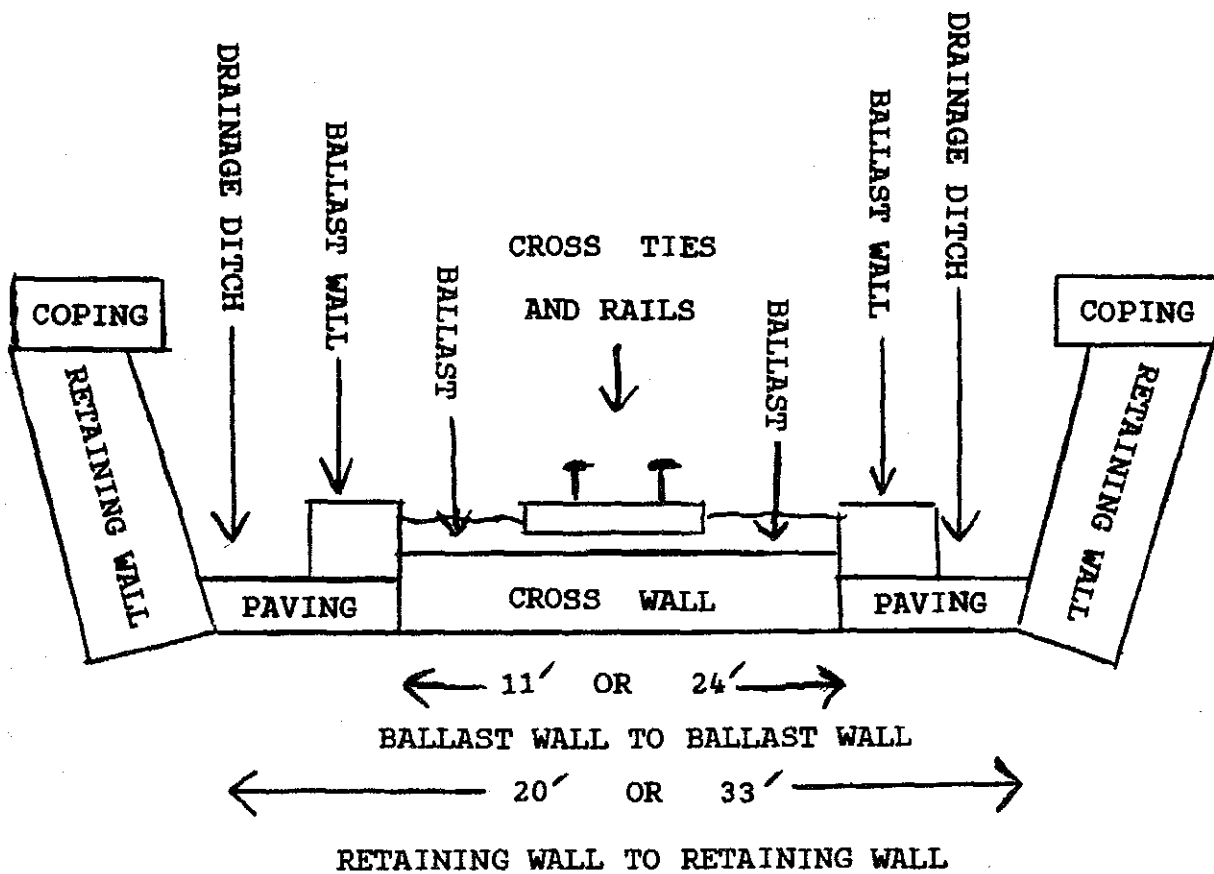
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SITE PLAN, CANADIAN APPROACH



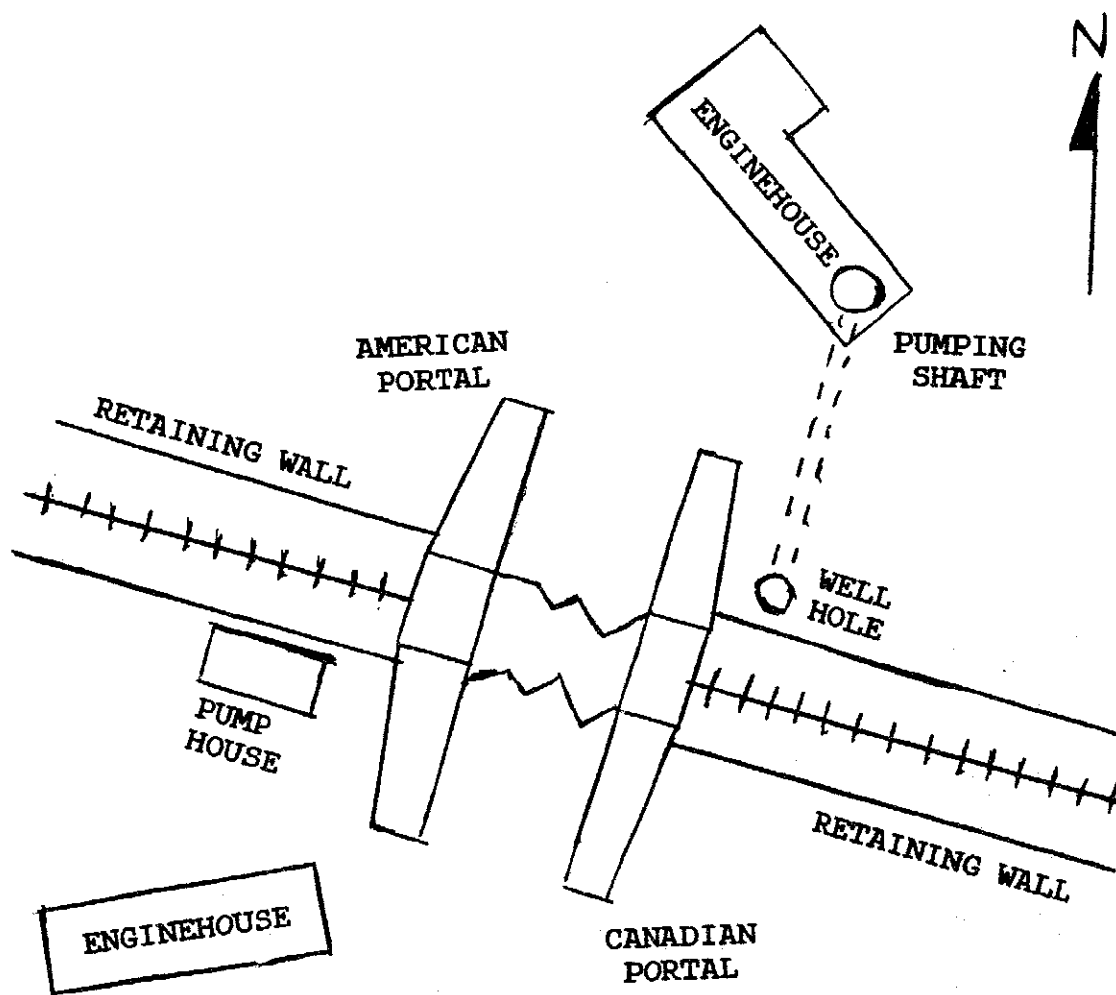
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TYPICAL CROSS SECTION, BOTH APPROACHES



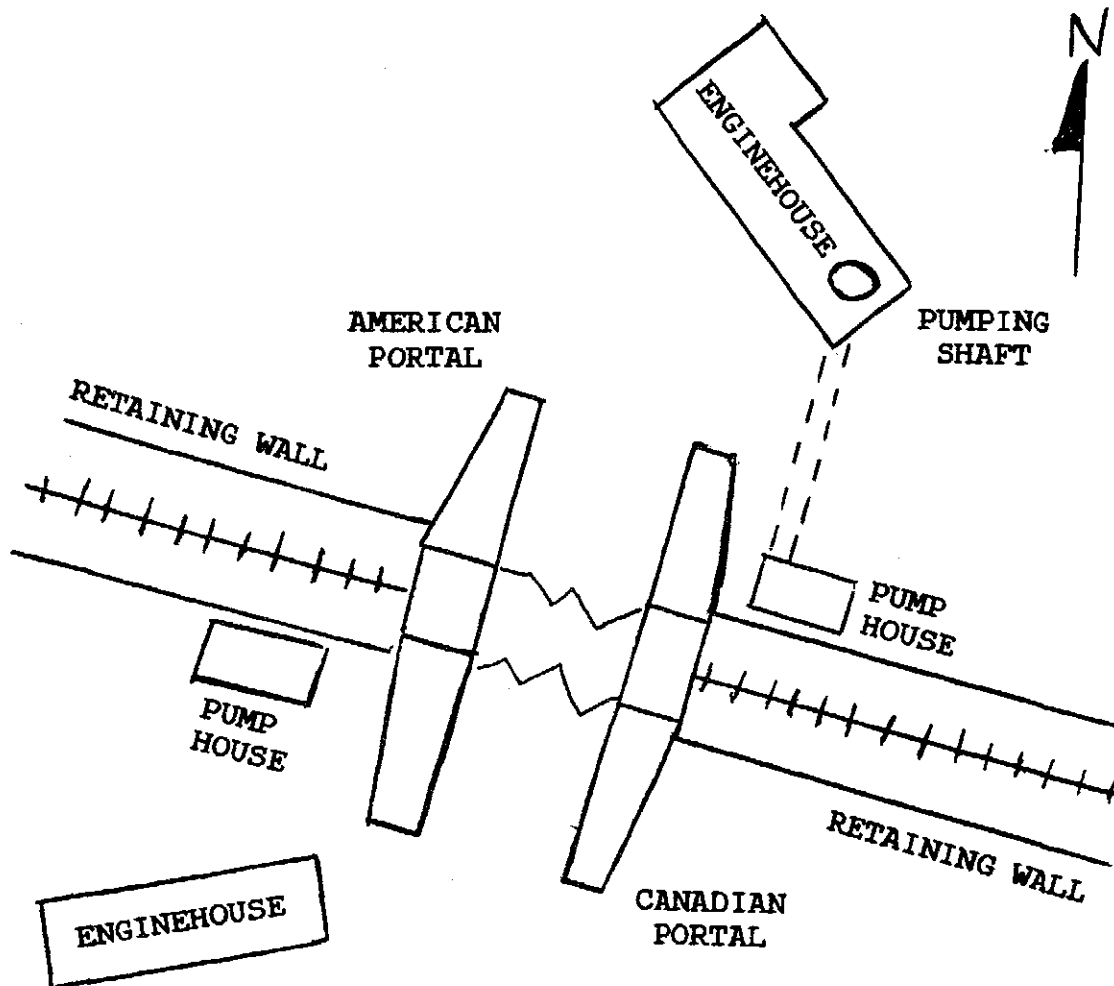
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SITE PLANS OF PORTALS, 1891



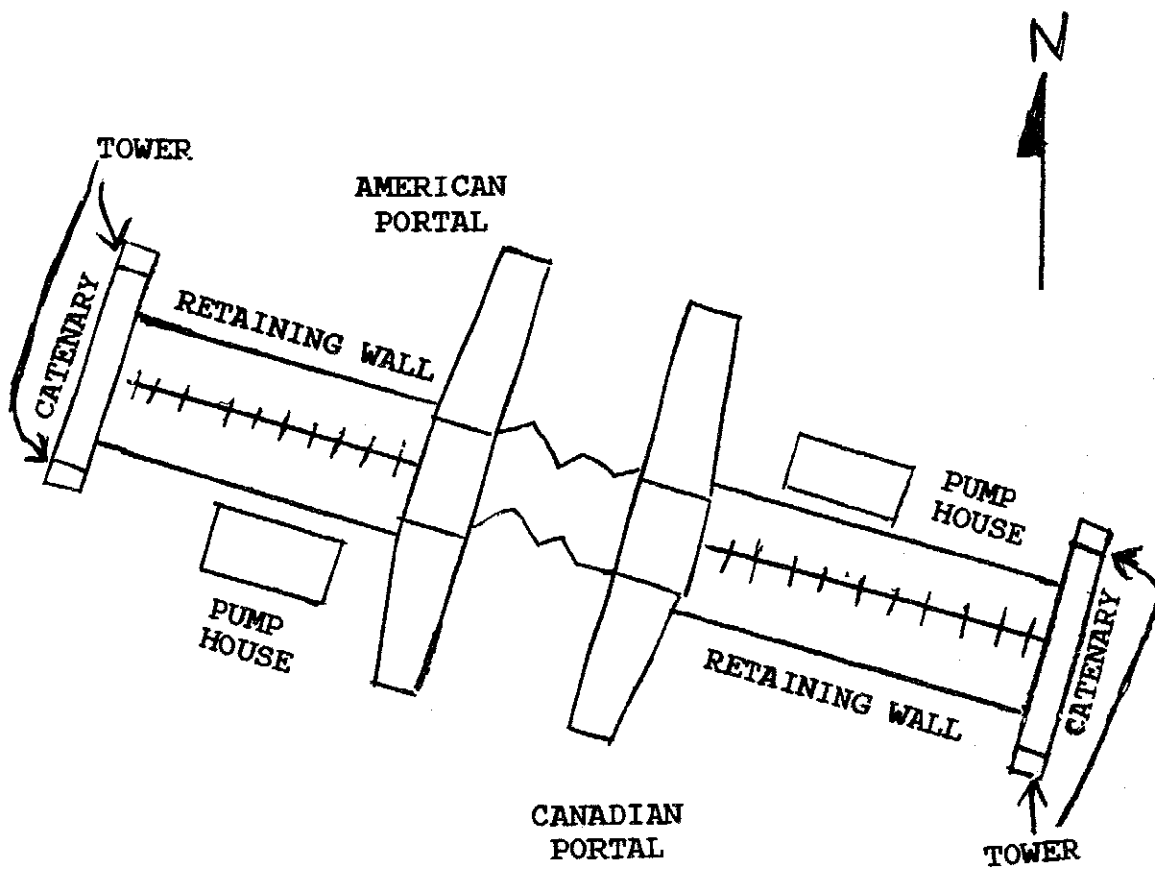
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SITE PLANS OF PORTALS, 1893



ST. CLAIR TUNNEL
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SITE PLANS OF PORTALS, ca. 1910



ST. CLAIR TUNNEL
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SITE PLANS OF PORTALS, 1958 - 1993

